

NORTH AMERICAN PARASITIC COPEPODS OF THE FAMILY  
ARGULIDÆ, WITH A BIBLIOGRAPHY OF THE GROUP  
AND A SYSTEMATIC REVIEW OF ALL KNOWN SPECIES.

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By CHARLES BRANCH WILSON.

*Department of Biology, State Normal School, Westfield, Massachusetts.*

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INTRODUCTION.

The present paper is the first of a series, now in course of preparation, on the parasitic copepods, based primarily on the large collection of this interesting group belonging to the U. S. National Museum, which has been placed in the author's hands for study. The great majority of the specimens came originally from the U. S. Fish Commission, and in addition all the unassigned material at the disposal of the Commission was turned over to the writer by Dr. H. C. Bumpus and Dr. Hugh M. Smith, to be added eventually to the National Museum collection. To Dr. Bumpus the author is also under obligation for the innumerable facilities in the way of collecting and studying living material which are always attendant upon a summer spent in the U. S. Fish Commission laboratory at Woods Hole.

Further acknowledgment is made of much valuable assistance rendered by Dr. Smith, who has placed every facility at the author's disposal, particularly of the inland stations of the U. S. Fish Commission, where no work of the kind has ever been done before; by Prof. Jacob Reighard, director of the station at Ann Arbor, Michigan, who discovered the new species *Argulus americanus*, and who has spared no pains to secure just the material asked for, and finally by Mr. Vinal N. Edwards, whose ability as a collector has placed so many other investigators under obligation.

Hence while these papers are to be primarily reports upon the National Museum collection, it is purposed to combine with them the notes and results obtained from the work at the U. S. Fish Commission, and to add also considerable that has come through private research, in order that they may be made as complete as possible.

Since this is the first attempt made in America upon this great crustacean group, it will, even at its best, of necessity be found deficient.

## HISTORICAL.

In compiling the bibliography here presented it was quickly found that but a single species, the European *Argulus foliaceus*, had been studied at all completely. In fact, with the exception of three papers, one by Dana and Herrick (1837), another by Thorell (1864), and the third by Kellicott (1877), all the work done outside of mere systematic enumeration and description of species has been upon this one form. From it has been obtained practically all the knowledge hitherto possessed of the ontogeny of the entire group, with its important bearing upon their systematic position. Dana and Herrick (1837) do picture a larval *Argulus catostomi*, but the accompanying description is so brief as to have very little practical value. And Kellicott's interesting description of a larval *Argulus* (1880) had the misfortune to be published in a periodical that died at the end of the first volume, so that it has remained virtually unknown.

Moreover, both *A. foliaceus* and *A. catostomi* and Kellicott's *A. stizostethii* are fresh-water forms, and hence absolutely nothing has been known of the development of the large salt-water representation of the group, which, as we shall see, is very similar to that of Kellicott's species.

While it does not change the accepted ontogeny in any of its great fundamental principles, it will be found to be radically different in many of the details.

Although the entire group was thus for a long time represented by the single species, yet such a meager representation was more than offset by a remarkably wide distribution.

*A. foliaceus* was found quite commonly throughout the larger part of Europe, and quickly became well known. Singularly enough, subsequent discoveries have brought to light only two other European species. All the rest of the group, with some exceptions, have been found in American waters, and since the four new species here recorded are also American, it seems as if Kroyer's original statement that the great American continent is the proper habitat of the Argulidæ were likely to prove true.

But since more than half the entire group and eight out of the thirteen North American species are marine, Thorell's notion that this family is partial to fresh water must be set aside.

These facts ought at least to correct such statements as that made in Parker and Haswell's Text-book,<sup>1</sup> that *Argulus* "is an external parasite on fresh-water fishes—carp, stickleback, etc."

In the face of such facts it is all the more remarkable that no American zoologist has ever investigated the group.

Dana and Herrick (1837), Kellicott (1877 and 1880), Gould (1841), and Dana (1852) have each described new species. The first three

<sup>1</sup> First volume, p. 531.

descriptions are well written and quite complete, but the other two are almost worthless. Afterwards Dr. S. I. Smith, in the Invertebrates of Vineyard Sound (1874), described three new species and mentioned two of the others as probably occurring in the vicinity. These six descriptions, with an annotated List of Described Species, by Richard Rathbun (1884), comprise all the American literature upon the family.

No one since Jurine's day (1806) has compiled a bibliography of the Argulidæ, and but once (Thorell, 1864) has there been any attempt to present a review of all known species.

These facts at once warrant the following attempt, and guarantee that it will be of necessity more or less defective. But it is hoped that it may be of service as a basis for future work.

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#### ECOLOGY.

The problems of parasitism and its attendant degeneration are among the most interesting in the whole realm of ecology, and nowhere can they be studied to any better advantage than among the parasitic copepods.

We can find here every grade of parasitism and can easily follow the resultant effects in the habits and morphology of the parasites themselves. There are forms like *Argulus* which not only move about all over the body of their host, but also change frequently from one species of fish to another, and can even leave their host at will and swim about freely, sometimes for several days, before returning.

Retaining thus completely their powers of locomotion we should not expect nor do we find in them any degeneration, but rather such

a modification of the various organs especially used in parasitism—e. g., organs for clinging to their host, for piercing after blood, etc., as will the better adapt them to their specific use.

Then we find forms like *Caligus* which roam about freely over their host's body but do not apparently leave it voluntarily, though they can swim well enough when compelled to do so.

Here also we should not expect any marked degeneration, but rather a more complete adaptation of the various organs.

The first evidence of degeneration in this genus lies apparently in the inclination toward free swimming and not so much in the ability to perform it. In these two large genera, *Argulus* and *Caligus*, the males and females differ but slightly, and in some species of *Argulus* they may even be approximately of the same size. The fact that the Argulidæ do not carry their eggs about with them tends still farther to eliminate the sexual differences, while in the Caligidæ the presence or absence of the long egg pouches with the attendant modifications of structure constitute the chief sexual distinctions.

Not so, however, in forms like *Pandarus*, for here both sexes usually fasten themselves in one place and remain there for a long time. They are also so dissimilar in habits and structure that the males have been hitherto placed in an entirely separate genus (*Nogagus*), and the two sexes have been proved to belong to the same species only by being repeatedly found in actual coition. As is usual in such cases the female is the more degenerate and can only crawl about slowly; she is so heavy and clumsy that she can not swim at all.

Here then is evidence of structural degeneration, not very marked as yet, since fully developed swimming organs are retained though they can not be used in the adult state.

The male *Pandarus*, on the contrary, not only retains the locomotor structures but can use them, being able to swim about freely whenever occasion demands.

Again there are forms like *Philicthys* in which both the male and female have become practically incapable of locomotion, but are still found free in the mucous canals and sinuses of fishes. In them the locomotor organs are markedly degenerate having dwindled to mere stumps without joints or setæ.

And, finally, we find forms like *Chondrucanthus*, *Anchorella*, and *Lernæa*, in which the female is absolutely incapable of motion, being fixed in one position for life, while the male has dwindled to a mere pigmy adherent to some part of the female's body. The male can still move about somewhat but the female has lost all trace of every appendage except those which serve to fasten her to her host.

It is purposed in these papers to bring out as fully as possible such interesting gradations, the present paper, of course, being confined to the Argulidæ.



These are wholly external parasites, and though sometimes found upon the skin or the fins, they are usually confined to the branchial cavity of their host. They may be sought on the inner wall of the operculum or in the shallow pocket behind the posterior gill arch, but are never found upon the gills themselves except through accident. They cling to their host by means of the anterior maxillipeds which are modified for this purpose into sucking disks, somewhat similar to those upon the arms of Cephalopods. And by a sort of walking motion of these same suckers they are enabled to scuttle about quite rapidly over the fish's skin so long as it remains moist. But they are unable either to fasten themselves to, or to make any progress over, a dry surface. The posterior maxillipeds are also modified into clasping organs armed with hooks at the tips, spines, and setæ along the sides, and a large plate on the basal joint whose surface is usually raised into rough papillæ, and whose posterior edge is furnished with three stout spines whose chief use seems to be to act as a firm brace while the pointed proboscis is being thrust forward into the flesh of the host in order to draw blood. And finally the basal joints of the anterior antennæ are developed into a pair of enormous curved hooks which assist somewhat in holding the *Argulus* to its host. But their chief use is apparently to keep the anterior edge of the carapace firmly in position while the proboscis is being worked.

Whether the *Argulus* remain upon the outer skin or in the branchial cavity it is continually subjected to considerable friction as the fish moves about through the water, especially if its host happens to be a fish of rapid movements, and there is an absolute certainty that it will be washed off if its hold is loosened for ever so short an interval.

To lessen the friction as well as to get the full use of its grasping organs, the *Argulus* (and the same is also true of the *Caligidæ*) always takes a position with its own longitudinal axis parallel to that of its host, and its head pointing in the same direction. In this position all the grasping organs just mentioned work together to prevent any sliding backward over the fish's skin. In addition, the lower surface of the carapace, more particularly at the anterior margin and along the edges, is quite thickly studded with short triangular spines, which point downward and backward, and catch firmly in the skin of the host. At the bases of both pairs of antennæ, and in many species, just behind the mouth and between the bases of the second maxillipeds are paired spines much larger and stouter, which evidently serve a similar purpose.

Though there may be little evidence of degeneration in these Argulids, therefore, there are abundant modifications to suit their acquired parasitic habits.

Upon the death of its host an *Argulus* leaves the body at once if it be in the water and swims about actively in search of a new victim.

If the fish has been removed from the water the parasite usually remains within the branchial cavity since this retains moisture longer than any other portion of the external surface. It is no uncommon thing to find them alive there several hours after the fish's death.

Upon removal to an aquarium the Argulids are found to have retained their locomotor ability to a greater degree than any other group of the parasitic copepods.

And there is no distinction of sex in this, for males and females alike swim about with as much freedom and as great rapidity as any of the so-called free copepods. And their sucker feet enable them to rest by attaching themselves to the sides of the aquarium, to stones, algæ, or any other convenient surface, instead of by balancing after the manner of *Cyclops* and allied forms. In swimming, the four pairs of legs are used as the propelling agents, and are provided with a fringe of long plumose setæ for that purpose.

The abdomen is elevated at an angle of about 45 degrees with the plane of the body and seems to serve somewhat as a rudder, but the most of the steering is accomplished by a flexion of the thorax on the head carapace. The result is an easy gliding motion, wholly destitute of the jerkiness so characteristic of free copepods, and more resembling that of *Artemia* and *Branchipus*. They usually move with sharp turns in nearly every direction, often making a complete summersault, or turning upward and scuttling along back downward on the under side of the surface film of the water after the manner of some snails.

But though their ordinary motion is slow and easy, they can dart about with considerable rapidity upon occasion.

The length of the plumose setæ on the swimming legs seems to determine in great measure the rapidity of movement. In some species (*laticauda*, *versicolor*, etc.) the setæ are long and stout, while in others (*niger*, *alosa*, etc.) they are short and weak. It follows that the former species are capable of much more rapid and energetic motion than the latter.

In an aquarium these Argulids seldom exhibit the disagreeable propensity shown by the Caligidæ of crawling up as far as possible on the sides of the aquarium above the surface of the water and remaining there until dead and dried up.

On the contrary, they are easily kept in confinement and make docile and highly interesting laboratory material.

As a natural consequence of its freedom of motion, an Argulus is not as closely confined to a single species of fish as are the other copepod parasites. This fact is very apparent from an examination of the list of hosts following the description of each species (p. 704).

It is to be remembered in this connection that our knowledge of these American forms is as yet extremely meager. When some of them come to be known as well as the European *A. foliaceus*, the

host list will probably approach more nearly to the fabulous length which it has reached in that species, and may even include frog tadpoles or salamanders. At all events, it is pretty safe to predict that future observations will swell the list of hosts for nearly every species.

Not merely is the same species of *Argulus* found upon many different kinds of fish, but even the same individuals must of necessity frequently change their host. This follows as a result of their habit of egg laying.

Unlike other copepoda, the eggs are not carried about in sacs attached to the body, but are fastened to stones, to the bottom, or to any convenient surface. This necessitates the desertion of its host by the parasite during the period of egg laying, with little chance of ever finding it again, and with at least the possibility that another fish of the same species can not be found at once. This is especially true of the males, which are very ardent during the breeding season, as noted long ago by Jurine (1806), and often leave their host to roam about in search of a female. This desertion of the host at the spawning time is also confirmed by the origin of some of the material now under consideration.

The types of Professor Smith's new species are all recorded as taken apart from fish, two specimens of *A. laticaula* from among algae in August and another taken in a tow net early in September; a single specimen of *A. latus* taken in a tow net at the surface July 1, and three specimens of *A. megalops*, also in a tow net, July 8. Again, *A. foliaceus* is reported as having been found among *Anacharis* in a canal near Edinburgh, Scotland, on August 26. Six of the seven specimens were roaming about free, while the seventh was attached to a stickleback (1895).

And finally, the actual voluntary desertion of their host has been observed several times in aquaria, not merely when the *Arguli* were harbored by a different species of fish from that upon which they were found, but also when host and parasite were not separated at all, but placed in the aquarium together (1880). To be sure, even in the latter case, the surroundings were more or less artificial, but it hardly seems as if they could be enough so to account wholly for the restlessness exhibited by the *Arguli*. The fish very quickly quieted down and acted in a perfectly normal manner. That the parasites did not become equally quiet renders it very probable that there must be some foundation for such nomadic habits in their ordinary behavior under normal conditions.

It is not to be inferred, however, that an *Argulus* has no preference in the choice of a host.

On the contrary, it is probable that, like other parasites, each species prefers a certain kind of fish, or at the most a few different and probably closely related kinds.

But we may reasonably infer that, after withdrawal from its host for the purpose of egg laying, if an *Argulus* is unable to find another fish of the same species it is willing to take almost any temporary host obtainable, transferring afterwards as opportunity offers. In confirmation of such an inference the following experiments were made on *A. catostomi* and *A. versicolor* for fresh-water forms and on *A. laticauda* and *A. megalops* from salt-water fishes.

1. *A. catostomi* is usually found upon the common "sucker," *Catostomus commersonii* (Lacépède), from which it was originally obtained and named, but it also occurs, and in the author's experience even more abundantly, upon the chub sucker, *Erimyzon sucetta oblongus* (Mitchill).

It was desired to keep some of these parasites through the breeding season and also to ascertain, if possible, how they find and attach themselves to their host. But suckers are large and clumsy fish, difficult to transport, and requiring large aquaria. Added to this is the fact that the easiest method of obtaining them at the season when the *Arguli* are breeding is by spearing, and that this usually kills the fish.

For these reasons they were removed from the suckers and transported to the laboratory in jars. It was evident, however, that they could not be kept for any length of time without a host, and accordingly several species of fish were tried, the sunfish (*Lepomis gibbosus* Linnaeus), the dace (*Notropis megalops* Rafinesque), the yellow perch (*P. flavescens* Mitchill), and a species of minnow, locally known as the "mummichug." When the fish were placed in the aquarium, the *Arguli* very unexpectedly paid no attention to them and did not appear to recognize their presence in any way, and yet several days had elapsed before the fish could be obtained, and the parasites must have become quite hungry.

But they continued swimming about in their usual lazy, erratic fashion, often passing very close to one of the fish, but never seeming to realize that it might become a possible host, until they actually ran plump into it. Then, however, they made up for lost time, fastened themselves to the fish's body instantly, and eagerly sought for a place to pierce the skin and obtain some blood. On these small fish the bases and surfaces of the fins (including the tail), and the thin skin under the throat were favorite localities. They stopped at one of these places long enough to obtain a good meal and then passed forward and tried to crawl beneath the operculum.

If they failed in this on account of the small size of some of the fish they seemed content to remain upon the external surface, and in this way specimens were carried successfully through the breeding season and a fine lot of eggs obtained.

There was no hesitation in attaching to any of these fish, and there seemed to be no choice between the species.

2. *A. versicolor* lives upon the pickerel, *Lucius reticulatus* Le Sueur. Here again we have a fish so large as to be difficult of transportation alive, and very troublesome to keep in captivity.

But even the attempt was rendered impossible in the present experiment by the fact that the fish from which the parasites were obtained were taken through the ice in January and were all dead when examined. Accordingly the Arguli were transported to the laboratory, and this time some of the redbin shiners (*Notropis*) which had been used for bait were found to be the most available material for temporary hosts.

In this instance the parasites were placed directly upon the redbins. They attached themselves at once, seeming to prefer the neighborhood of the dorsal and ventral fins, and, so far as watched, making no attempt to crawl under the operculum.

They did not seem to irritate the fish perceptibly, although they could be plainly seen to crowd forward under the scales to pierce the skin. They were kept in this way more than two months, and had almost reached the breeding season when an unfortunate accident killed them all.

Remaining thus upon the external surface where they could be easily watched, it was seen that the individual parasites changed about considerably from one fish to another.

One of the redbins proved particularly attractive, and often had nearly all the parasites (15 in number) on his own body.

He was no larger than some of the others, but was very plump and vigorous.

This living upon minnows is in direct confirmation of the observations of Claus (1875) upon the two European forms, *A. foliaceus* and *A. coregoni*. But the present observations differed markedly from his in one respect; either these redbins were not as yet educated to the use of parasites as food, or they did not relish such a diet. Although they were fiercely hungry when obtained, having been kept without food since they were caught in the fall, no one of them took any notice of some Arguli which were placed free in the aquarium for that purpose.

Finally one of the parasites fairly rubbed against a redbin's nose in swimming about, and the latter, unable to resist such a call, opened his mouth and apparently swallowed the Argulus. But it was only apparently, for in a moment or two the Argulus was forcibly ejected uninjured, and no further attempt was ever made to swallow one. Indeed, none of them disappeared till the final accident which killed them all.

3. *A. laticauda* and *A. megalops* live upon many of our common salt-water fish, and some of them were desired for experiments similar to those tried upon the fresh-water forms.

But it would obviously be impossible to transport them with their

hosts for any distance inland. Through the kindness of Mr. Vinal N. Edwards many specimens of these two species were removed from their hosts, placed in fresh salt water, and sent through the mail from Woods Hole to Westfield, Massachusetts.

The *A. laticauda* were taken from eels and had evidently just finished their egg laying; the *A. megalops* were from flat fish (*Paralichthys*) and were still full of eggs. Some of the females laid upon the sides of the bottle on the way, and the remainder deposited their eggs after reaching the laboratory.

But how could any experiments upon a change of host be tried with these forms? No marine fish were obtainable alive, and if they could have been procured, sufficient salt water to keep them was manifestly out of the question so far inland.

It was remembered that these parasites infest many fish, like eels, salmon, herring, etc., which are migratory in their habits, and some which pass from salt into fresh water, or the opposite, during their migrations. It becomes an interesting question, therefore, whether the parasite is able to accompany its host through these changes or not.

It was determined first to try a change from salt to fresh water without the presence of any host whatever. Accordingly several specimens of each of these two salt-water species were placed in a dish of salt water, which was then slowly changed to fresh by the addition of a few drops of the latter at a time.

They gave apparently no attention whatever to the change, but continued to swim about in the fresh water as they had done in the salt. Indeed, they manifested so little appreciation of the change that another lot was transferred directly from salt to fresh water. These appeared a little irritated at first, but quickly recovered and manifested no subsequent difference in demeanor. Then a host was supplied them in the shape of a small minnow, to which they attached themselves readily and upon which they lived for several days.

These experiments would indicate very strongly that *Argulus* at least, among the copepods which infest the various salt-water migratory fishes, is capable of continuing upon its host as the latter passes up some fresh-water river in search of a suitable spawning place. It furnishes good proof also that the salt-water as well as the fresh-water forms are capable of changing about from one species of host to another.

In this connection it is well to recall the fact that the species *catostomi* was first discovered in the Mill River near New Haven, Connecticut, where the water is distinctly brackish (1837).

The same species was afterwards found by Gage (1886) in Cayuga Lake, Ithaca, New York, in perfectly fresh water. It has also been

found by the author in abundance in the Connecticut River and its tributaries near Springfield and Chicopee, far above tide water, and also in several small ponds and streams farther east in the State.

The ability to use almost any fish for a temporary host affords a reasonable explanation of the appearance of many species in the host lists whose presence would otherwise be difficult of explanation, as, for example, the frog tadpoles of *A. foliaceus*, etc.

It also readily explains why the Arguli should be found on mud-loving and bottom-frequenting species during the breeding seasons, while they rarely occur on the same species at other times. A study of the lists herewith presented (p. 704) will show that the place to look for these parasites during the breeding seasons is upon those fish which remain at or near the bottom where the Arguli go to deposit their eggs, while at other times the same parasites may be found only upon entirely different fish.

In consequence of such nomadic habits I heartily indorse Claus's remark that it is entirely unfitting to designate any species of Argulus by the name of the fish upon which it may be found. Later observation has always added other hosts and has often produced a long list like that for *foliaceus*, *laticauda*, and *megalops*. And in the majority of instances the first host has not proved to be the true one. Indeed, from the data and experiments here presented, it will be seen that in order to determine what species, if any, is to be regarded as really the host of an Argulus will require careful observation extending over at least a year.

The names already given to American species derived from the name of their host have been especially unfortunate. In Gould's *A. alosae*, *Alosa* was the name given by Cuvier to the shad upon which this parasite has not yet been found.

Again, the *A. catostomi* of Dana and Herriek proves to be far more common on *Erimyzon* than upon *Catostomus*.

The *A. funduli* of Kröyer is based upon a single specimen taken from a species of *Fundulus* (named *F. limbatus* by Kröyer) in the vicinity of New Orleans. As we have just seen, there is the possibility if not the probability that this parasite may have sought the *Fundulus* as a temporary host during or after egg laying. And the size of the female which is here for the first time described precludes any consideration of a species of *Fundulus* as its permanent host.

In contrast with these misnomers Smith's new species, *latus*, *laticauda*, and *megalops*, were fortunately based upon specimens taken at or near the surface, and whose hosts were wholly unknown. Profiting by these experiences the new species here described have been given names in no way connected with their host, and yet one of them (*versicolor*) has been found as yet only upon a single species of fish, *Lucius reticulatus* Le Sueur.

In spite of the fact that the Argulidae move about so freely and show almost no trace of degeneration, their food is exactly the same as that of the other parasitic copepods, namely, the blood of their host. They obtain this by means of a long eversible proboscis or dart, which is formed by a modification of certain of the mouth parts, and which they thrust through the skin, afterwards sucking up the blood as it flows from the wound. The base of the dart is continuous with the base of the regular mouth parts, from whence it extends forward between the bases of the two pairs of antennæ, lying in a shallow groove which occupies the center of this ventral surface.

When swimming about freely the proboscis is withdrawn as far as possible and carried in the groove in a manner similar to that of the hemipterous insects. But upon the fish's body the anterior end is dropped down against the skin, into which it is pushed diagonally by a slight forward movement of the body assisted by its own eversion.

Naturally the parasites seek those portions of the body where the skin is thin, but more especially where the blood vessels are near the surface, such as the inner surface of the operculum and the fins. When fastened to the outside of the body of a scaly fish the scales naturally obstruct the passage of the dart. To obviate this the Argulus burrows beneath a scale with the anterior edge of the carapace, lifting the scale up and pushing the body forward until the dart is brought to the naked skin underneath. They remain in one position for an hour or more, as though the blood were obtained slowly.

As to the relation between parasite and host, it is not probable that the former ever become a serious menace to the life of the latter except under favorable conditions.

No matter how badly a fish may be infested with these pests it has a chance to get rid of them pretty thoroughly at least three times a year at the breeding seasons. Of course, if a fish for any reason has become debilitated and then happens to get an extra dose of parasites the results are likely to be fatal. But it is worthy of note that the Argulids prefer strong, healthy fish and are not often found upon sickly ones.

Their bodies are comparatively so small, are flattened so strongly, and are held so firmly to the fish's skin that they must occasion almost no inconvenience in the natural movements of their host.

When we consider the artificial propagation of fish, however, the conditions are entirely changed. Professor Smith long ago called attention to the subject of copepod parasitism in its special practical importance to all those engaged in raising fish confined in ponds or other restricted areas, especially in aquaria. The artificial surroundings always make more or less of a drain on the fish's vitality, and, since the numbers are restricted, there is a resultant concentration of the evil effects produced by the parasites. The very fact that the latter choose the strongest and most healthy fish is one of the worst things



that could happen, since it tends to keep the general tone down to the level of the weaker and poorer individuals. Hence the breeders of fish and the keepers of aquaria often find these parasites troublesome pests, as was clearly stated by the very first observer, Leonard Baldneur (1666).

In the manuscript left in the public library at Strassburg, while speaking of what he calls the "pou des poissons" (*A. foliaceus*), he says that it is seldom found in the environs of Strassburg except upon trout, and that it frequently kills them, especially those which are kept in ponds.

In view of these difficulties the following experience will prove of interest and may become of practical value by suggesting an easy and effective means for keeping the pests within due bounds: In the town of Warren, Massachusetts, is a small pond artificially increased to a few acres in area by means of a dam. This pond was stocked with carp and bass several years ago. It is fed by two small mountain brooks, and having no other outlet except the sluiceway of the milldam, it furnished an excellent breeding place, in which the fish seemed to thrive well, but during the late summer and autumn of 1899 the fish began to die off in considerable numbers. Their dead bodies were found floating at the surface with no apparent signs of disease or injury, nor did careful and repeated examinations suggest any explanation of the epidemic. But the pond contained an abundance of a green floating alga which proved to harbor myriads of small crustacea, *Diphnia*, *Sida*, etc.

The devastation continued through the winter, and another visit was made in the spring in the hope of finding some clew.

This was just at the time suckers were running, and several of them were speared in a pool below the dam. On examining the walls of their gill cavities between 30 and 40 specimens of *A. catostomi* were obtained, many of them with ripe sexual products. These were taken home and kept in aquaria, where the females deposited their eggs, which hatched out a month later into a fine lot of larvæ. On showing the adults to the gentleman who owned the pond he said they were found on many of the fish caught, but were never considered specially harmful.

He also said that the brooks which fed the pond contained many suckers, most of which were infested with these parasites, a statement afterwards verified. It was determined to try the effect of a concentration of the parasites upon a few fish.

Accordingly 15 or 20 of the Arguli were put in a small aquarium and fish of various kinds from the pond were put in with them. These fish, which included roach, dace, and sun-fish, were put in one at a time, so that the entire number of parasites could concentrate upon each of them separately.

They fastened upon the ventral surface and upon the sides of the body near the operculum; the dace and roach resented the attack and thrashed around vigorously, but to no avail; the bream accepted the situation without protest. After remaining in the aquarium over night the dace and bream were found dead and floating around with exactly the same appearance as the dead fish in the pond. This, of course, suggested that if the number of parasites was sufficient in the pond, or if for any reason they concentrated upon a few fish, they might produce the fatality. The solution of the whole problem lay in the number of the parasites, and every effort was made to discover a reason for their abnormal abundance as well as that of the other small crustacea already mentioned. The reason came from a wholly unexpected source: as already stated, a fine lot of larvæ were obtained from the eggs laid in aquaria. One of the marked differences between the larva and the adult appears in the anterior maxillipeds. In the larva these terminate in an enormous barbed claw instead of a sucking disk. They are, therefore, clasping organs of a highly developed kind, but repeated efforts failed to induce the larvæ to use them for that purpose.

On the contrary, the latter continued to swarm near the surface of the water on the side of the aquarium toward the light, like other copepods, and paid no attention whatever to several fish which were put in with them as possible hosts.

Finally two small dace from the same pond were tried, but no more attention was paid to them than to the other kinds.

Not so with the fish however, for no sooner had they recovered from their fright at being handled than they turned round and ate up every last larva—several hundred in all.

Inquiries suggested by this action and made as soon as possible revealed the fact that for the three years previous to the fatality among the fish the proprietor of the pond had dragged it thoroughly with a seine and removed all the small dace and roach and sold them for live bait. Here was a satisfactory explanation of the abnormal abundance of copepods and cladocerans, and in it there is a plain suggestion that this question of parasitism is not such a one-sided affair as it appears at first sight. The adult *Argulus* may become a menace to the adult fish, but in its larval stages it no doubt often furnishes food for the young of the same fishes or of others.

It also suggests that a proper amount of protection for the small fish, such as dace, roach, etc., which inhabit our ponds and streams will be one of the most effective means of guarding against any formidable increase in the numbers of these parasites.

Especially is this true in the case of restricted areas like artificial fish ponds, hatcheries, aquaria, etc.; here every one of the conditions deleterious to the fish is advantageous to the parasite, and the latter is

always practically assured of a suitable host and assisted in any effort it may make toward concentration. These facts render it certain that if the breeding of Arguli is once started in such places it will rapidly assume dangerous proportions unless checked at the very beginning.

The introduction, repeated if necessary, of some of the small fish that naturally prey upon crustacean larvæ, could do no possible injury, and in the light of this investigation bids fair to prove an effective remedy.

#### SUMMARY.

1. The Argulidæ are external parasites, usually confined to the branchial cavity of their host.

2. They cling by means of the anterior maxillipeds, which are modified into sucking disks for this purpose, and by a walking motion of these same disks they scuttle about over the fish's skin so long as it remains moist. They can not fasten to a dry surface.

3. They always take a position with the long axis of their bodies parallel to that of their host and with their heads in the same direction. They are kept from slipping backward, as the fish darts through the water, by the sucking disks just mentioned, by large curved hooks on the bases of the anterior antennæ, by stout spines on the bases of both pairs of antennæ and often between the bases of both pairs of maxillipeds, by rough plates on the bases of the posterior maxillipeds, usually with three stout spines along their posterior border, and by short triangular spines all over the ventral surface of the carapace, but especially numerous along the anterior margin. All these spines point diagonally downward and backward, and at the slightest backward movement they catch firmly in the fish's skin, and, of course, the greater the pressure the more firmly they hold.

4. The Argulidæ retain their locomotor ability to a greater degree than any of the other parasitic copepods. Both males and females swim with an easy, gliding motion, free from jerkiness. The four pairs of legs serve as locomotor organs, and steering is accomplished chiefly by a flexion of the thorax on the head carapace, though the abdomen assists somewhat. The length of the plumose setæ on the legs seems to determine the rapidity of movement.

5. In consequence of its freedom of motion an Argulus is not confined to one species of fish, but can change its host at pleasure. Hence the host list is quite large for all the well-known species and will probably increase with further observation.

6. Both sexes, but especially the males, leave their host at the breeding season, since the eggs are not carried about, but are deposited on some favorable surface, usually at the bottom. Hence at least three times a year an infested fish has a chance to get rid of these parasites.

7. After leaving its host thus, if the *Argulus* can not readily find another individual of the same species it can live for a time upon almost any fish, or even upon frog tadpoles, changing afterwards as opportunity offers.

8. The species of *Argulidae* infesting migratory fish are probably able to change with their host from salt to fresh water or the reverse.

9. The food of these parasites is the blood of their hosts, obtained by means of a long evertible proboscis, which they thrust through the skin, afterwards sucking up the blood as it flows from the wound.

10. Under natural conditions it is not probable that the *Arguli* often become a serious menace to the life of their host; but in the artificial propagation of fish and in restricted areas, especially aquaria, they may, and often do, prove troublesome and sometimes kill off the fish. It has been proved that small fish—dace, roach, etc.—eat *Argulus* larvæ voraciously. Hence the protection of such fish in our ponds and streams and their introduction into restricted fish ponds and aquaria would probably prevent any serious multiplication of the parasites.

#### ONTOGENY.

The *Argulidae* are unlike other copepods, both free swimming and parasitic, in that the female does not carry her eggs about with her, but deposits them upon some convenient surface and there leaves them to care for themselves.

Claus states (1875) that *A. foliaceus* has three breeding seasons in the year—the first at the end of May or the beginning of June, the second during the middle or latter part of July, and the third in the latter part of September. Without being able to affirm, from actual observation of a single species throughout the entire year, that the American forms have similar breeding seasons, there are many facts which point strongly to such a conclusion in both the salt and the fresh water species.

1. *A. catostomi* certainly breeds in May and June, large numbers of eggs and larvæ having been obtained both by Dana and Herrick and by the author at that season.

2. *A. stizostethii* certainly breeds in August, Kellicott having obtained eggs (and larvæ) from ripe females taken from fish (*Stizostethium*, species) in the Niagara River at that season.

3. *A. megalops* and *A. laticarula* certainly breed in October, the author having received ripe females from Woods Hole at that season, from which were obtained eggs and subsequent larvæ.

4. Numerous very small *A. megalops* less than 2 mm. in length were obtained on August 20 and September 1, while *A. alosæ* of corresponding size were found on August 13. Since the *megalops* larva is nearly 1 mm. in length when hatched, it is evident that these young could not have come from the eggs of the previous year, but must

indicate a breeding season early in the year, corresponding to that of catostomi.

5. Females of the following species, full of eggs that appeared to be perfectly ripe, have been taken at Woods Hole at the dates given and are now in the collection of the National Museum: *A. megalops*, August 31, September 1, October 14, October 30, November 21; *A. laticauda*, August 14, August, October 20, 28, 30; *A. dlosæ*, August 13, September 24 and 27, October 5.

6. From a knowledge of the breeding habits which have just been given, the capture of males swimming about freely at the surface or isolated upon fish which they do not infest at other seasons in the year furnishes corroborative testimony to the breeding seasons.

Of such we find the following: *A. megalops*, male, from surface, July 8; two males from surface, August 31; one from a Minnow, July 14; one from Sea Robin, August 23. *A. laticauda*, one from among algae, August; one from Tom Cod, October 20; four from Skate, October 19; one from Bonnet Skate, August 9.

The cumulative evidence thus adduced makes it practically certain that the salt-water forms, at least, have three breeding seasons in the year, corresponding to those given by Claus for *A. foliaceus*. It would not be expected, of course, that the actual dates would correspond exactly.

The place chosen for egg deposition is usually a stone or other hard material, the glass sides in an aquarium being usually selected. Van Beneden writes (1883) that "la mère, au lieu de porter sa progéniture dans un sac qu'elle traîne avec elle, la confie successivement à l'un ou l'autre poisson, comme la coucou qui dépose des oeufs dans le nid d'un bec-fin, et le jeune Arguie, en naissant, jouit de toute sa liberté."

Jurine (1806), whose observations on the other habits of these parasites are so admirable, expressly says that he has never found any eggs upon the fish which serve as hosts for *A. foliaceus*, and his testimony has been corroborated by every one of the long list of collectors since his day, except Van Beneden (1891).

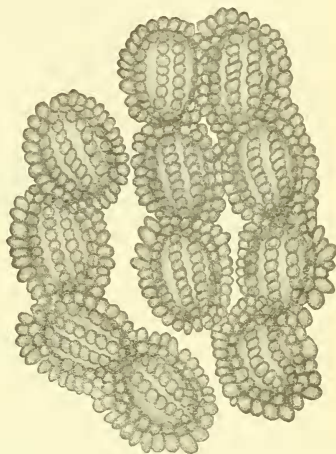


FIG. 1.—A SINGLE CLUSTER OF THE EGGS OF ARGULUS CATOSTOMI. ACTUAL SIZE OF ONE EGG 0.45 BY 0.3 MM.

Such a condition as the latter portrays, to be of any advantage to the Argulus, would necessitate that the larva fasten itself to the fish immediately upon emerging from the egg. In that case the expression "Jouit de toute sa liberté" would hardly convey the correct meaning. Van Beneden does not give this as his own personal observation, and it will require considerable additional proof before it can be received. The probability is strongly against it.

When a suitable place has been chosen by the female the eggs are deposited end to end in parallel rows, one egg at a time. The rows are quite short and may contain anywhere from 3 or 4 to 15 or 20 eggs, and there may be from 3 to 6 or 7 rows together. The female then rests for a while before depositing a similar lot in another place. Often in an aquarium the entire lot of several hundred eggs will be deposited close together on one side, but they are always broken up into these smaller lots determined by the intervals of rest.

As nearly as can be judged from a careful comparison of the statements of various authors with original observations, there seems to be

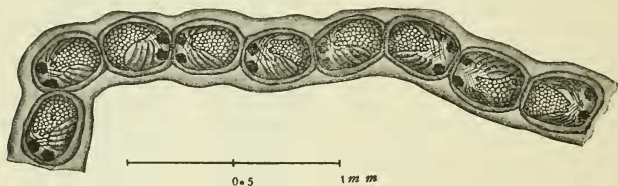


FIG. 2.—EGGS OF ARGULUS MEGALOPS ABOUT READY TO HATCH. ACTUAL SIZE OF ONE EGG 0.35 BY 0.28 MM.

a tendency in *A. foliaceus* toward a fewer number of rows (two being very common) and more eggs in each, while in *A. catostomi* the rows are more numerous and shorter, giving to the individual batches of eggs more of an elliptical outline (fig. 1).

In *A. megalops*, on the contrary, all the eggs observed have been laid in single rows, with from 6 or 8 to 20 or 25 eggs in each (fig. 2). Jurine (1806) has given us an admirable description of the process of egg-laying in *A. foliaceus*, so accurate that it has not since been altered in a single essential particular. I quote it in full.

Toutes les fois que l'argule-mère a pondu un oeuf, elle fait un petit pas qui avance son corps en lui donnant un peu d'obliquité: de sorte que le second oeuf se trouve nécessairement placé en avant et à côté du premier. En alternant ainsi ses pas, le troisième oeuf se trouvera dans la direction du premier, le quatrième dans celle du second, et ainsi de suite; de manière qu'ils seront disposés sur deux colonnes, dont la première comprendra tous ceux dont les nombres sont impairs, et la seconde ceux dont les nombres sont pairs. Telle est la marche que suivant ordinairement ces femelles dans leur ponte; cependant il arrive quelquefois qu'elles déposent leurs oeufs sur trois, quatre ou cinq colonnes, ou qu'elles les éparpillent; mais ce dernier cas n'a lieu que lorsqu'elles sont inquiétées. Il arrive encore que les femelles entrecoupent leur ponte et qu'elles la font en trois ou quatre reprises: alors elles changent de place et se transportant ailleurs.

It would be expected that the method would differ in different species, and it actually does vary in several particulars when witnessed in *A. catostomi* and *A. megalops*.

In the former species the female does not twist from side to side nor do the eggs alternate in two adjacent rows, as described by Jurine.

In the deposition of hundreds of eggs no female was seen to deposit two rows at the same time, but only a single short row.

These eggs of *A. catostomi* are ellipsoidal, quite large (0.45 mm. by 0.3 mm.) and are yellowish white when first laid.

But they soon become dirty, turning first a darker yellow and finally a rusty-brown color. The thick jelly with which they are covered when they come out of the oviduct quickly hardens in the water and forms a dense covering, very difficult to break open without injury to the egg inside. But the chief characteristic is the form which this jelly envelope assumes. At first it is spread in an even layer over the entire egg, but the surface quickly breaks up into longitudinal grooves with sharp ridges between. The grooves may or may not twist a little spirally around the long axis of the egg, but the intervening ridges always crack transversely and separate into short masses which usually assume quite a perfect ellipsoidal form, the same as that of the egg itself.

These ellipses may be arranged end to end in a row, similar to the arrangement of the eggs, or they may be placed side by side, or may even stand out at right angles to the surface of the egg like rounded warts or papillæ (fig. 1).

On further hardening, the same grooving and breaking up into papillæ may appear on the surface of each of the original ellipsoids, so that such eggs come to have a set of doubly crenated ribs, a mark which will distinguish them wherever found.

The eggs of *A. americanus* resemble those of *catostomi* in that the jelly envelope breaks up similarly into longitudinal rows of papillæ, but there is never any double crenation. In addition to the rows of papillæ they are always from one to several much larger, irregular masses of jelly attached to each egg envelope.

The other species, *A. megalops*, is the first of the salt-water Argulids whose method of egg deposition has ever been watched, and the process is therefore worthy of a somewhat more detailed description. Through the courtesy of Vinal N. Edwards about a dozen females with ripe eggs were obtained from Woods Hole, on October 30, 1901.

These were sent by mail in a small bottle of salt water and were all alive when received; some of them had already begun to deposit their eggs on the sides of the bottle on the way.

The remainder of the eggs were secured on the sides of a small glass aquarium to which the Arguli were all transposed.

In this case also the female hunted for a suitable spot when about to

deposit her eggs. Having found one she crawled along slowly over it by the walking motion of her sucking discs. When she had advanced far enough to compensate for the length of her body she stopped and violently contorted and twisted her thorax and abdomen, bending them from side to side and backward and forward. During these contortions an egg could be seen descending the oviduct toward the opening between the posterior pair of legs. Just as the egg reached this opening the thorax was bent sharply upward (dorsally) away from the glass; at the same time the abdomen was bent sharply downward (ventrally) toward the glass, so that thorax and abdomen formed a right angle with each other, the angle being held some little distance away from the surface. Into the space thus formed the egg was protruded, being seized firmly on either side by the basal joints of the posterior pair of legs as soon as it emerged from the opening of the oviduct. The posterior lobes on these basal joints were pulled as far forward as possible and then drawn together, catching the egg between their inner surfaces and carrying it backward into the little space under the flexed thorax-abdomen. Here it was pressed for an instant against the support (glass) to which it adhered firmly.

The Argulus then moved forward a distance equal to the long diameter of the egg with its jelly envelope and the process was repeated. The eggs thus adhere to each other in rows as well as to the glass, each row containing ten or a dozen eggs and being usually quite straight. The process is rather slow, a little more than a minute (seventy seconds) being occupied in the deposition of a single egg. In this species one female did not lay more than 40 or 50 eggs, and often the last ones were deposited singly and scattered about indiscriminately.

It seems probable, however, that this number does not represent the entire batch of eggs, but that the females had deposited a part of them before being captured.

After the first one or two eggs are laid the abdomen of course has to ride up over them as the Argulus moves forward.

The base of the anal sinus rests upon the rounded upper surfaces of the eggs, which it fits snugly, while the lateral edges are bent down on either side. The abdomen thus curved over the eggs probably acts as a guide for the Argulus, enabling her to place the eggs in approximately straight rows.

Furthermore, it would seem as if the anal papillæ, which in *megalops*, as so often in other species, are situated at the very base of the sinus, might act as feelers, slipping over the eggs lengthwise and down into the hollows between them, enabling the Argulus to tell when she had moved forward just the right distance.

At all events, whether the rows are straight or crooked, the eggs are always the same distance apart.



It will be noted that this account differs considerably from that of Jurine. In the present instance, as in the case of *A. catostomi*, already cited, no female deposited her eggs in two columns, but every time they were arranged in a single row. This was due to the fact that the short move ahead, instead of being a one-sided affair, throwing the body at an oblique angle to the line of progress, was a uniform and even advance, the body remaining always parallel with the line of advance. All through the egg laying the females manifest considerable excitement; the legs, with the exception of the posterior pair, are moved incessantly and with great rapidity in the same way as when swimming. As soon as one row of eggs is finished the female darts rapidly about the aquarium for some little time, twisting and turning somersaults as if crazed. These motions gradually slow down and finally cease, when she begins to hunt for a new place in which to deposit another row of eggs. These observations, coupled with the fact that females with their ovaries only half full of ripe eggs have been repeatedly taken upon fish frequenting the bottom, make it reasonably certain that they do not deposit their eggs all at once, but at intervals, and in the meanwhile they may even obtain a square meal from some convenient fish.

The female carries sperm, obtained from previous copulation, in her abdominal pouches, and each egg is fertilized as it is laid. If one of the eggs be removed shortly after deposition and examined under a high power the spermatozoa can be plainly seen swarming around the jelly envelope.

Notwithstanding this method of fertilization, the egg laying excites the males even more than the females, and they dart about in a vain endeavor to get hold of some of the latter.

At first two species (*megalops* and *laticauda*) were mingled in the same dish; all of the females that were laying were *megalops*, while most of the males were *laticauda*. But this fact did not seem to make any difference; the *laticauda* males were as much excited as those of *megalops*, and, neglecting the females of their own species, which were quiet and had finished their laying, they made every effort to seize the *megalops* females; but, together with the *megalops* males, they were constantly repulsed. Evidently the copulation takes place previous to egg laying, and the female relies wholly upon the sperm stored up in the seminal pouches.

These eggs of *A. megalops* are ellipsoidal, like those of *foliaceus* and *catostomi*, but are not as large, being only 0.35 mm. long and 0.28 mm. wide, and yet we shall presently see that the larva which emerges from them is one of the largest yet described.

The eggs are light yellow when first laid, afterwards becoming dirty and brownish, but never as dark as those of *catostomi*.

The eggs of *A. stizostethii* are more nearly spherical, about 0.41 mm. in diameter, and are milk white when first laid, soon changing to light yellow. In both species the eggs remain smooth till hatched, never showing any crenations.

The long diameter of the egg becomes the longitudinal axis of the larva, but all the larvæ in the same row are not arranged with their heads in the same direction. Every here and there one will be found reversed so that heads of adjacent ones come together, as is common in the egg strings of the Eucepods. Curiously enough in this lot of *megalops* eggs it seemed to be quite regularly the fourth ones which were thus reversed, but probably such regularity was accidental.

The number of eggs deposited by a single female is given as 100 by Claus (1875) for *A. foliaceus*, and as 400 by Jurine for the same species; as 1,200 by Dana and Herrick (1837) for *A. catostomi*, and as 50 to 300 by Kellicott (1880) for *A. stizostethii*.

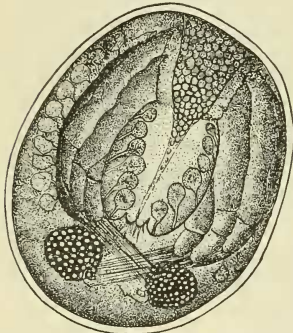


FIG. 3.—LARVA OF ARGULUS MEGALOPS JUST READY TO HATCH.

black eyes first become visible. The egg then rapidly clears and it can be plainly seen that the body of the larva is folded upon itself, the abdomen and the posterior thorax being turned forward along the ventral surface of the head thorax, while the legs are folded forward and inward with the long rowing setæ crossing one another on the mid line (fig. 3).

The time required for hatching varies greatly. In *A. foliaceus* it is given as about four weeks (Claus), and as thirty-five days (Jurine); it is nearly the same for *A. catostomi*, thirty-five days (Dana and Herrick), and from twenty-eight to thirty-five days in the author's experience.

This time proves to be a sort of golden mean in Argulus development, other species varying from it in both directions. The period for *A. americanus* is only about half as long. Eggs which were laid on June 7, 1902, and which were sent to the author by Professor Reighard from the U. S. Fish Commission station at Ann Arbor, Michi-

In the author's experience the largest number obtained from a single female was between 500 and 600 for *A. catostomi* and 65 for *A. megalops*. But it is probable in the latter case that the females had already deposited some eggs before being captured, since the ovaries were not more than half full.

After being deposited the eggs become opaque and no trace of the development can be seen through the jelly envelope until two or three weeks before hatching, when the

gan, began to hatch on the 25th, a period of only eighteen days. And yet, from actual tests, the temperature of the aquarium did not rise above 65° F. during that time.

For *A. megalops* the time is much longer: the eggs obtained from Woods Hole were laid October 30 and 31; they did not begin to hatch until December 12, and the larvæ had not all emerged before December 30 (sixty days), nearly double the time required for the two first species. And there is another consideration which makes this disparity even greater than it seems at first sight. No statement of the conditions under which development took place is made by any of the authors save Kellicott (1880). Dana and Herrick, however, do mention (1837) that the female of *A. catostomi* laid her eggs upon the sides of the aquarium, and it is to be presumed that they remained there until hatched. Probably also the times recorded by the other authors were obtained from eggs kept in aquaria.

Such at least is the case with the eggs of both *catostomi* and *megalops* observed by the present author. And in both instances the water of the aquarium stood at about the same temperature (72° F.) as that of the room in which it was kept.

This would not be much of a change from their normal environment for the eggs of *catostomi*, for they were not laid till May 14, and were kept through June into July, hatching from June 11 to 20. The temperature of the water in the pond from which the females were taken must have risen during that time to within a comparatively few degrees of the room mentioned. But in the case of *A. megalops* there was a radical difference in the environment; these eggs were taken from the open ocean on October 30, and kept through November and into the latter part of December. Hence a temperature of 75° would be at least 30° or 35° higher than that of the salt water at Woods Hole during those months. This would mean, of course, that the eggs developed much faster than in their normal surroundings, so that we must add eight or ten days to the period just given before comparing it with the other species.

Hence incubation is fully twice as long in *megalops* as in *foliaceus* or *catostomi*. But even this record is surpassed by that of *A. stizostethii*. Kellicott records (1880) that the eggs laid in his aquarium on August 28 did not show the dark eye dots until October 5, and did not begin to hatch till November 17, a period of eighty-one days! Here the author distinctly states that the tank was kept at the temperature of the room, and hence something would need to be added to even such an enormous period as this before it would fairly represent the length of incubation under normal conditions. It is also stated that these eggs were kept out of the light, and Kellicott thinks that this influenced the incubation. Possibly it might offset the increase in temperature, but we must remember that in depositing her eggs under normal conditions the female *Argulus* must needs often get them in the shade. It

would seem fair, therefore, to allow the record to stand as given, so that this incubation period would be a little longer than that of *megalops*.

There are other considerations also which make it practically certain that the incubation period of these two species would be of about the same length, and longer than that of *foliaceus* and *catostomi* (p. 660).

Both Jurine and Claus have given a detailed account of the larva of *foliaceus* and the various molts through which it passes.

Claus calls especial attention to the fact that the egg contains a relatively large yolk, and that the embryo attains a correspondingly unusual size and advanced development before hatching. This occasions the period of increase in the prenatal development as compared with other parasitic copepods.

If this be true of *foliaceus* and *catostomi*, we would naturally infer that in *megalops* and *stizostethii*, with their incubating period twice as long, the larva must be even further developed, and such we shall find to be the case.

In the following account of larval development the facts in relation to *foliaceus* have been taken from Jurine (1806), Leydig (1850), and Claus (1875), those in regard to *stizostethii* from Kellicott (1880), while those in reference to *catostomi*, *megalops*, and *americanus* are from original observations. It is hoped soon to publish a full description of these latter larvæ.

On first issuing from the egg the larvæ of *foliaceus* and *catostomi* bear a striking resemblance to a partly developed Caligus, as noted at some length by Claus.

We find a shield-shaped anterior portion of the body corresponding with the cephalo-thorax in Caligus, three free segments corresponding with the second, third, and fourth thoracic segments in Caligus, and a large abdomen carrying papillæ armed with setæ, corresponding with the papillated abdomen of the Eucepods.

In the larvæ of *A. megalops* and *A. stizostethii* the resemblance is not quite so apparent, chiefly on account of their more advanced development, but we can still distinguish the same regions easily. (Plate VIII.) Hence the nauplius, the metanauplius, and even the earlier cyclops stages are passed by these Argulus larvæ inside the egg, and they come forth in one of the more fully developed cyclops stages. All the segments and appendages which are to appear in the adult are present at birth, and in addition the *foliaceus* and *catostomi* larvæ have extra temporary appendages in the form of a pair of mandibular palps, which are used as locomotor organs up to the first molt, and then disappear.

We should expect larvæ so very well developed at birth to be much larger than the ordinary crustacean nauplius, and they rather exceed our expectations. The larva of *foliaceus* is 0.6 to 0.75 mm. in length, that of *catostomi* 0.7 to 0.8 mm., while the *megalops* larva is 0.8 to

0.85 mm. long, and the larva of *stizostethii* reaches almost 1 mm. (0.98). And this, too, in spite of the fact that the adults of *megalops* and *stizostethii* are smaller than those of *catostomi* and *foliaceus*.

That the sizes should be thus reversed in the larvæ is further good proof of the difference in their relative development, i. e., not only does the greater similarity of the appendages to the adult form attest the more advanced development of the *stizostethii* larva, but its body is actually nearly twice as large as that of the *foliaceus* larva.

All the larvæ have the general shape of the adult, save that in *foliaceus*, *catostomi*, and *americanus* the body is somewhat narrowed posteriorly, while the anal papillæ are much larger and terminal instead of basal. The carapace is relatively broad and barely covers the bases of the first swimming legs.

In *catostomi* the width of the larval carapace is relatively less than that of the adult, but in the other species it is practically the same. Its border is fringed with fine cilia, among which are scattered stouter, seta-like tactile organs which are much larger than the cilia and about twice as long.

The free thoracic segments diminish much more rapidly in these three larvæ than in the other two species, but each segment bears a pair of swimming legs or their rudiments.

The abdomen in the three species just named is also very narrow, almost triangular in shape, and terminated by the large anal papillæ. In the *megalops* and *stizostethii* larvæ, on the contrary, the abdomen is as wide as the last thoracic segment, is broadly ovate in form, and in the *megalops* larvæ is terminated by two short, bluntly acute lobes, with the anal papillæ at the base of the intervening sinus. In *stizostethii* the abdomen is abruptly truncated posteriorly and the anal sinus is so shallow that there are practically no lobes at all, but the anal papillæ are situated close to the anus, and therefore must be regarded as basal rather than terminal, like those of *megalops*, to which they also correspond in size.

The first antennæ, and in *megalops* and *stizostethii* the second also, have already assumed nearly their permanent form.

In all the species the first antennæ are three-jointed,<sup>1</sup> the basal

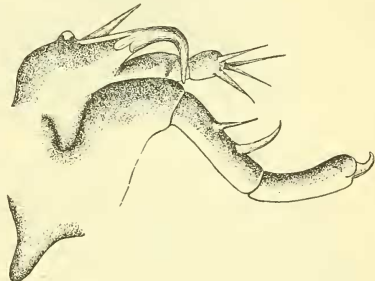


FIG. 4.—FIRST AND SECOND ANTENNÆ OF NEWLY HATCHED LARVA OF ARGULUS MEGALOPS.

<sup>1</sup>Kellicott says (1880) that the first antennæ of *stizostethii* are four-jointed, but they are really the same as those of the other species. The apparent difference comes from his regarding the basal joint as double rather than single, in which case these first antennæ would be four-jointed in all the species.

joint being very large and flat, furnished with large sickle-shaped hooks on its lateral, and smaller ones on its anterior, margin, and evidently functioning as an organ of prehension.

The two terminal joints are small and armed with delicate tactile bristles, and they just as evidently function as tactile organs. On the bases of both pairs of antennæ in all the larvæ are found stout spines directed backward as in the adult (fig. 4).

In the larvæ of the first group the second antennæ are very different in form from those of the adult, and serve as one of the two principal locomotor organs. They are very much elongated, extending

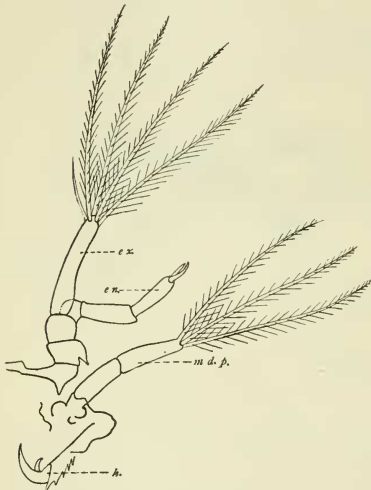


FIG. 5.—SECOND ANTENNA AND LABIAL PALP OF NEWLY HATCHED LARVA OF *ARGULUS FOLIACEUS* (MODIFIED FROM CLAUS). *ex.*, AND *en.*, EXOPOD AND ENDOPOD OF THE SECOND ANTENNÆ; *h.*, HOOK CONNECTED WITH BASE OF THE SAME; *md. p.*, TEMPORARY MANDIBULAR PALPS.

far beyond the carapace, and are made up of three parts, a 2-jointed basipod arising just posterior to the eyes, each joint being armed with a short spine, a stout endopod also 2-jointed and tipped with a curved spine, and a 1-jointed exopod bearing at its tip four long plumose setæ and a short thumb-like one on the inner side. These setæ can be approximated or separated at pleasure (fig. 5).

In contrast with these the second antennæ of the *megalops* and *stizostethii* larvæ are of ordinary length and consist of a good-sized basal joint extending back about opposite the center of the eyes, where it is armed near the median line with the usual blunt spine, a long

middle joint armed with two spines on its anterior surface, and a short terminal joint tipped with a stout hook.<sup>1</sup>

When straightened these antennæ reach considerably beyond the border of the carapace, but the latter nearly covers them when they are partly folded, the position in which the larva usually carries them. Hence they can not take any part in locomotion.

Next in order posteriorly we find in our three larvæ a pair of ap-

<sup>1</sup> Kellicott says that the second antennæ in *stizostethii* are four-jointed, but whether he has again regarded the basal joint as double can not be decided either from his figure or from the text. The probability is that he has, for the antennæ in the adults are like those of megalops.

pendages which are entirely wanting in the other two species. These are the temporary mandibular palps, which are attached to the sides of the upper lip, and which serve, up to the first molt, as the second of the two principal locomotor organs. They are made up of two parts, a simple basal portion and a 2-jointed terminal portion bearing at its tip three long plumose setae similar to those on the second antennae in the same species, and, like them, capable of being approximated or separated at pleasure (fig. 5).

The anterior maxillipeds are not modified in any of the larvæ into sucking disks, but retain instead their primitive form of stout clasping

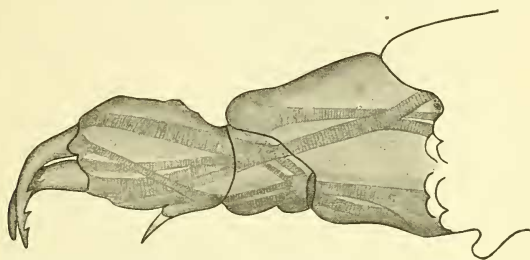


FIG. 6.—ANTERIOR MAXILLIPED OF NEWLY HATCHED MEGALOPS LARVA SHOWING MUSCULATURE.

organs. They are 4-jointed and furnished at the tip with two strong sickle-shaped hooks, placed side by side, the ventral one of which is armed with three sharp barbs on its inner border. These organs are thus similar to the so-called clasping legs of the parasitic Eucopepods (fig 6).

The posterior maxillipeds are very much smaller than the anterior, and serve as accessory clasping organs, the same function that they perform in the adult. They are 5-jointed in all the larvæ, and are armed on the inner surfaces of each of the four basal joints with spines, stout setae, or rough papillae, the kind, number, and arrangement varying considerably in the different species, but all evidently designed for

the same purpose. These maxillipeds are terminated by two movable, strongly curved claws, and a rounded knob ending in a sharp spine, knob and claws being placed side by side in a line dorso-ventrally, the knob being dorsal. The basal joint is considerably elongated longitudinally and bears upon its posterior border a short, stout spine (two in *megalops*) in the same place where the spines on the squamiform appendages of the adult subsequently appear (fig. 7).

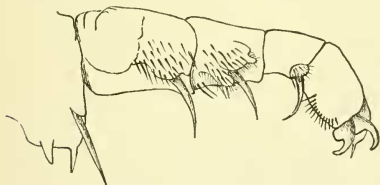


FIG. 7.—POSTERIOR MAXILLIPED OF NEWLY HATCHED MEGALOPS LARVA SHOWING ARMATURE.

gated longitudinally and bears upon its posterior border a short, stout spine (two in *megalops*) in the same place where the spines on the squamiform appendages of the adult subsequently appear (fig. 7).

In *megalops* and *stizostethii* all four pairs of swimming legs are present, and they have the same number of joints and are as fully developed as in the adult. The basipods are 2-jointed, the proximal joints decreasing and the peripheral increasing in length from in front backward. The exopods are 1-jointed and carry two long rowing setae which are plumose and movable like those on the antennae and mandibular palps in the other species. The endopods of the first pair are 3-jointed, the first and second joints carrying sharp spines on their posterior border and the third joint terminating in two similar spines placed side by side. The endopods of the three posterior pairs are 2-jointed and carry but a single rowing seta.

By referring again to fig. 3 it will be seen that these four pairs of fully developed swimming legs can be seen through the egg envelope a day or two before the larvæ emerges.

When it does come forth, therefore, we find it using these same appendages exclusively for locomotion, i. e., *it begins to swim at once in the same manner and by means of the same appendages which it is to use all through life.*

We find in this respect a marked contrast between these two forms, one (*megalops*) from the salt water, and the other (*stizostethii*) from the fresh water, and the three other fresh-water species we are discussing. In the latter only the first pair of legs is at all developed, the other three pairs being very rudimentary, mere stumps in fact, immovable, and hence of no possible use in swimming. These larvæ, therefore, are obliged to depend upon the second antennae and the temporary mandibular palps for locomotion, being aided only slightly, if at all, by the partially developed first pair of legs, i. e., *these larvæ begin to swim in an entirely different manner from the adult, and by means of appendages temporarily developed for that purpose, which afterwards entirely disappear.*

Thus in their development these larvæ show a partial metamorphosis, and stand as a connecting link between the other parasitic copepods (Eucopepods), with their complete metamorphosis through nauplius, metanauplius, and the various cyclops stages, and species like *megalops* and *stizostethii*, in which there is really no metamorphosis at all, at least no change in the number, position, segmentation, or function of the various appendages, but only a few comparatively trifling alterations in size and form.

Both the pointed, retractile proboscis and the mouth parts are present in all the larvæ. The latter take the form of a club-shaped protuberance projecting from the mid line of the ventral surface between the two pairs of maxillipeds.

It is made up of an upper and an under lip and a pair of mandibles, the maxillae not being yet developed. The chewing blades of the mandibles lie just beneath the upper lip, are sickle-shaped and curve in toward each other from either side.



In *foliaceus* and *catostomi* they are armed with a claw on their posterior border which reaches outside the lower lip, and are separated by the side walls of the mouth from the mandibular palps already described. In the *megalops* and *stizostethii* larvæ there are no palps and no claw reaching outside the lower lip, so that the mouth assumes almost exactly the structure of the adult, save for the lack of maxillæ (fig. 8).

With regard to the histology and internal structure, that portion of the intestine immediately behind the mouth and reaching into the first free thoracic segment is somewhat wider than the remainder and is sharply marked off from it by a constriction in the side walls and by much darker coloration. This is the stomach of the larva, and it sends out on either side a wide branch toward the edge of the carapace just

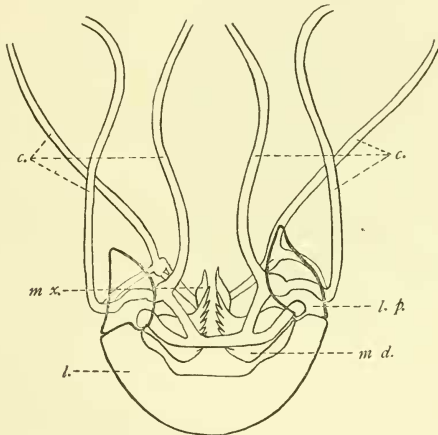


FIG. 8.—CHITIN SKELETON OF THE PROBOSCIS OF A NEWLY HATCHED MEGALOPS LARVA. *c.*, CHITIN FRAMEWORK; *l.*, LOWER LIP; *l. p.*, LABIAL PALP; *m. d.*, MANDIBLE; *m. x.*, MAXILLA.

behind the posterior maxillipeds. (Plate VIII.) The branches turn both backward and forward inside the edge, like a section of the stem and umbrella of a mushroom, and are crenated along their outer border. Both central portion and branches are so filled with yolk granules and oil globules as to be nearly opaque.

The remaining portion of the intestine in the free thoracic segments is somewhat narrower and is filled with much clearer cells. In the last segment it passes abruptly into a narrow cloacal portion which runs through the center of the abdomen as a narrow tube, and ends in the anus, which is a transverse slit situated just beneath the papillæ at the base of the anal sinus. All three parts of this digestive tube keep up a lively contraction, by means of which there is frequent interchange of their contents.

Outside the umbrella portion of the stomach branches, along the lateral and posterior border of the carapace, lies a row of one-celled skin glands with fine awl-shaped ducts leading radially outward to the very edge. These glands are more or less circular in outline and are strongly flattened dorso-ventrally. Their granular contents are arranged in fairly distinct rows radiating from the opening of the duct, which is a little removed from one edge, sometimes near the center.

This gives them somewhat the appearance of miniature palm-leaf fans laid side by side with their handles pointing outward.

In *foliaceus* these side rows are broken by a comparatively wide interval just opposite the base of the mouth, and the two groups thus formed consist, respectively, of 10 posteriorly and 4 anteriorly. There are also in this species a pair of similar glands in front of the first antennæ, a pair at the inner corners of the lateral eyes, a pair behind those eyes, and a group of four just in front of and one behind the lateral branches of the stomach, but there are none in the abdomen.

In the *catostomi* larvæ no glands can be found anywhere in the hundreds of preserved larvæ now at disposal, and in the *stizostethi* larva no mention of them is made, nor do they appear in the figure. In the *americanus* larva the glands are few in number, small in size, and are scattered about promiscuously in both carapace and abdomen, without any regularity. In the *megalops* larva, on the contrary, these glands are much more highly developed, and the largest and best of them lie in a row of six along either side of the abdomen some little distance from the edge (*g.*, fig. 9). In this species the rows along the edges of the carapace are continuous and number 21 or 22 glands each; there is an isolated group of 5 glands between the eyes at the anterior border of the carapace, 3 in front along the edge, and 2 behind them at the interior corners of the eyes. There are also on either side a group of 3 placed diagonally behind the eyes, another group of 2 just in front of the side branch of the stomach, one over the side of the stomach itself where this branch joins it, and a single large elliptical gland at the outer end of the terminal joint of the basipod in each of the swimming legs.

Although these glands are not found in the abdomen of the newly hatched larva of *foliaceus* (Claus) or *catostomi*, they appear there at a later stage in development, and in the adult of all forms which have been examined they are found scattered over the entire surface of the body, being gathered in groups in many places, e. g., in the lobes of the abdomen, the basal joints of the legs, etc. Their function has not been explained by any author, but that they are morphologically simple glands there can be no doubt. Their ducts open at the surface of the body, and under the influence of an alkaline solution a portion of the contents of the body of the gland is discharged through the duct in the form of globules (Leydig). Doubtless they are capable of simi-

lar action under normal conditions, and the more or less metamorphosed contents being thus discharged to the exterior would give them something of an excretory function.

The paired eyes are very large, being made up of many spherical or ellipsoidal facets loosely joined together.

Each eye is inclosed in a transparent blood sinus through which the blood circulates freely by means of three or more openings. The facets jut out quite a distance from the pigment, and along the anterior border of the eye, especially in the *megalops* larvæ, can be seen as transparent yellowish globules. They are proportionately much larger than in the adult.

The unpaired median eye is situated on the top of the posterior border of the brain. It consists of an X-shaped pigment body at the junction of three transparent lobes, shaped and arranged like the parts of a clover leaf. The pigment has a decided reddish tinge.

No heart is visible in any of these larvæ, but its place is supplied by several accessory structures, which produce an active streaming of the blood along practically the same channels as in the adult. The cellular substance between the surfaces of the

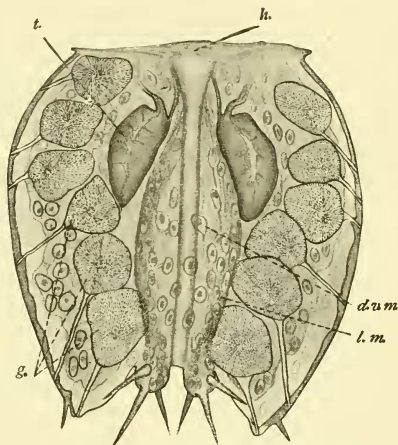


FIG. 9.—ABDOMEN OF NEWLY HATCHED MALE LARVA OF ARGULUS MEGALOPS. *d. v. m.*, DORSO-VENTRAL MUSCLES; *g.*, SKIN GLANDS; *h.*, POSTERIOR WALL OF HEART; *l. m.*, LONGITUDINAL MUSCLES; *t.*, TESTIS.

carapace, in the thorax outside of the stomach and intestine, and in the abdomen outside the sexual organs, is gathered into little islands, between and around which are blood lacunæ in free communication throughout the entire body. There is also quite a wide continuous peripheral sinus around the entire body, particularly in the abdomen. In and out of the lacunæ and through the peripheral sinus the blood is driven by a more or less rhythmical contraction of the following muscles.

In the abdomen between the peripheral glands and rudimentary sexual organs and the central intestine lies, on either side, a spindle of very well-developed longitudinal muscles (*l. m.*, fig. 9).

Scattered irregularly amongst these are short dorso-ventral, individual muscle fibers which are nowhere gathered into bundles (*d. v. m.*).

Most of these latter fibers, as well as those of the longitudinal muscles, are one-celled, and the central nucleus is plainly visible, with one or more long fibrous portions extending from either end. These muscle fibers are strikingly like those elsewhere described<sup>1</sup> in the veliger larvæ of nudibranchs and the pilidium larvæ of nemerteans, and in all probability the fibrous portion is developed in a similar manner by a fibrillar rearrangement of the protoplasm of the original cell. These muscles, both longitudinal and dorso-ventral, contract somewhat rhythmically and drive the blood from the space between them around the cloaca out into the posterior end past the anal papillæ into the peripheral spaces along the sides of the abdomen.

The second muscle to aid in the pulsation takes the form of a transverse dorso-ventral band or curtain lying at the posterior border of the last thoracic segment in just the position occupied later by the posterior wall of the heart (*h.*, fig. 9). This is attached to the side walls of the sinus between thorax and abdomen, but hangs loosely elsewhere, and on contraction produces two movements, one a pulling together of the side walls and the other a backward and forward movement of the center of the curtain. Both motions aid the streaming of the blood. Besides these muscles, which are directly concerned in circulation, there are others in the walls of the stomach and intestine, on the dorsal and ventral walls of the thorax, and even in the basipods of the legs, that must assist the process considerably. The internal tissues are so loosely put together and there is so much free communication between the various parts of the body that a vigorous contraction of any set of muscles, e. g., those in the basipods of the legs during swimming, must produce more or less of a flow of blood in the immediate vicinity.

The skin is so very transparent that even the transverse striation of the muscles can be readily seen through it, so that these larvæ afford one of the best objects for a study of crustacean musculature that could be imagined.

The skin being so thin and the blood circulating everywhere freely beneath it there is no difficulty in bringing about integumental respiration. Such respiration takes place more or less all over the body and does not seem to be exclusively concentrated in any one region. I agree with Claus when, correcting the statements of both Jurine and Dana and Herrick, he says that the abdomen has no more to do with respiration than some other parts of the body and is not as useful in this respect as the side flaps of the carapace. This does not mean that the abdomen does not function physiologically as a respiratory organ; it certainly does and its service is a very valuable one. But it does mean that this is not the only respiratory organ and probably not even the

<sup>1</sup>Activities of Mesenchyme in Certain Larvæ, C. B. Wilson, Zool. Bull., II, No. 1, p. 15. The Habits and Early Development of *Cerebratulus lacteus* (Verrill), C. B. Wilson, Quart. Jour. Mic. Sci., new ser., XLIII, p. 97.

best one possessed by the larva. In confirmation of such a view, witness the fact that in several of our largest species (*niger*, *catostomi*, etc.) the abdomen is proportionally very small, in *catostomi* so diminutive compared with the enormous head-thorax that it could not possibly keep the blood aerated.

The nervous system consists of a "brain," which is situated near the dorsal surface of the carapace just above the mouth and just beneath the unpaired eye, and a chain of ventral ganglia (Plate VIII, fig. 24). Of the latter the two anterior ones lie close to the mouth on the ventral surface and the four posterior ones lie beneath the stomach, and are so hidden by its opaque contents as to be visible only during contractions.

On the ventral surface of the brain on either side may be seen a small swelling, the beginning of the mouth commissure, which in later development surrounds the mouth and binds the brain to the anterior ventral ganglion.

Alongside the anterior border of the side branches of the stomach, well out toward the edge of the carapace, may be seen the paired shell glands first detected by Claus in the *foliaceus* larva. As will be seen on Plate VIII, they can be distinguished by the size and grouping of the cells. The walls are two-layered, and at the anterior corners may be seen the lumen of the duct.

In none of the larvæ is there visible anything, even under an oil-immersion lens, which can be definitely asserted to be the beginning of the asymmetrical ovary. And yet there are many reasons for believing with Claus that careful sectioning will reveal the rudiments of an ovary in all these larvæ.

He discovered it just after the first molt considerably developed and reasoned that it must have been present before.

But if this were true in *foliaceus* and *catostomi*, there is, of course, more reason for suspecting it in the much better developed larvæ of *megalops* and *stizostethii*. The probability of its existence is greatly strengthened by the fact that all the other reproductive organs in both sexes are present and plainly visible. The seminal pouches in the female consist of small, inversely pear-shaped bodies placed just inside the row of glands close to the base of the abdomen (*s. p.*, Plate VIII). The ducts from these glands and the papillæ on the ventral surface with which they are connected are not yet developed.

The testes in the abdomen of the male are much larger than these seminal pouches of the female and show the beginnings of a central lumen (*t.*, fig. 9). They correspond in position with the pouches and at their upper ends may be detected the beginnings of the vasa efferentiæ. None of the accessory copulatory organs are present on the legs of the male at this stage.

As soon as they emerge from the egg, therefore, the sex of the larvæ can be determined with certainty.

It is to be regretted that the *megalops* larvæ could not be carried beyond the initial stage, but they had to be kept in salt water, and the supply of salt-water fish and other life was necessarily limited so far inland. Although tried with several possible hosts, nothing could be found that was acceptable, and after living for ten days without any change they finally perished. We have also no record of the *stizostethii* larvæ beyond the first stage, and both must be left for future research.

The *foliaceus* and *catostomi* larvæ agree closely in their development; the first molt takes place about the fifth day and produces a radical change in the appendages (fig. 10). The long rowing branch of the second antennæ and the temporary mandibular palps disappear, the former being replaced by a structure similar to that in the adult, the latter never appearing again.

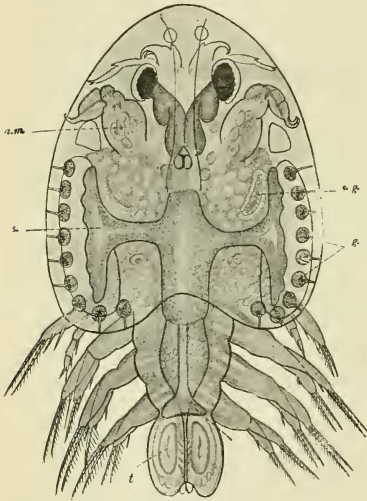


FIG. 10.—LARVA OF ARGULUS FOLIACEUS AFTER THE FIRST MOLT (FROM CLAUS). *a. m.*, ANTERIOR MAXILLIPEDS JUST BEGINNING TO CHANGE INTO SUCKING DISKS; *g.*, SKIN GLANDS; *h.*, HEART; *s.*, STOMACH BRANCHES; *s. g.*, SHELL GLAND; *t.*, TESTIS, SHOWING NOW A CENTRAL LUMEN.

The disappearance of these temporary larval organs of locomotion of course means that the permanent swimming legs have now become sufficiently developed to perform their normal function.

Though not yet like those of the adult in all details, these legs have the same number of joints and approximately the same structure. There has been a corresponding widening of the thorax and abdomen; the posterior border of the latter has become emarginate, and the

very much reduced papillæ are no longer terminal on each lobe, but lie close together in the center of the sinus just above the anus.

The seminal receptacles and testes have enlarged considerably and the former has acquired a thin cellular covering.

The unpaired ovary now appears as a row of small cells along one side or the other of the intestine posterior to the stomach. These cells increase in size, proliferate to the right and left and backward and forward, and their granular contents gradually change with further development.

They also change their position slowly, and finally come to occupy the whole central space beneath the stomach and intestine.

The heart can now be definitely located in the posterior thoracic segment as a triangular pouch with three valvular openings, one median and two lateral, backward into the abdomen, and a large aorta extending forward along the median line to the region of the brain. The two lateral posterior openings discharge blood into the side sinuses of the abdomen during diastole, while the flow of blood backward through the central opening is regulated by the transversely pulsating flap or curtain already described. The aorta pulsates with the heart, but the evidence seems to be in favor of regarding it as an aorta (Claus) rather than as the vestibule of the heart (Leydig), since it corresponds exactly in position and form with the aorta in many copepods, and is also destitute of any side openings.

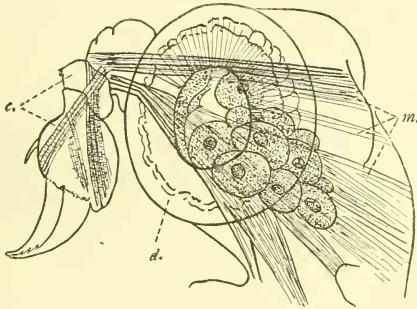


FIG. 11.—ANTERIOR MAXILLIPED OF FOLIACEUS LARVA AFTER SEVERAL MOULTS, SHOWING TRANSITION FROM A CLAW TO A SUCKING DISK (FROM CLAW). *c.*, OLD CLAW BEING GRADUALLY ABSORBED AND ITS MATERIAL USED TO MAKE THE NEW DISK *d.*; *m.*, MUSCLES.

The other changes at this molt are very slight; the first maxillipeds become somewhat thickened through the middle joints, making them spindle-shaped, and along the central axis in between the muscles may be seen a column of large elliptical cells with well-marked nuclei, from which are soon to be developed the sucking disks. These cells are present and distinctly visible in the megalops larva before the first molt.

A second shedding of the skin takes place three or four days after the first, and produces no perceptible changes except in size and in further development of the sucking disks on the first maxillipeds.

The second molt occurs about the tenth day, the third on the thirteenth or fourteenth day, the fourth on the sixteenth day, and the fifth on the twentieth day. During this time the larva gradually increases in size, and the details of structure both external and internal conform more and more to the adult form. This is especially notice-

able in the first maxillipeds where the sucking disks are gradually developed at the expense of the terminal segments and barbed hooks (fig. 11).

The sexual organs have been completed by the development of an oviduct in the female leading back to the sinus between the posterior lobes on the last pair of legs, and by the completion of the vasæ efferentiæ and the formation of ejaculatory ducts in the male. With the fourth molt the copulatory organs begin to show themselves on the legs of the male, and the sucking disks become capable of functioning as organs of attachment. Hence we must regard the larval stage as finished and the fifth period as the beginning of adult life. Subsequent molts follow at intervals of three or four days until, at the end of four weeks, the young Argulids become sexually ripe and the males are capable of the complicated process of copulation. They are now from 2.5 mm. to 3 mm. in length, and Claus states that in *A. foliaceus* the females must reach a length of at least 7 mm. before becoming ready for their first egg laying.

#### SUMMARY.

1. The female Arguli do not carry their eggs about with them, but deposit them in rows upon stones or other convenient hard surfaces and leave them to care for themselves.

2. The eggs are ellipsoidal in form, 0.35 to 0.45 mm. in length, and are placed end to end in the rows. They are covered with a gelatinous envelope, which swells and hardens on contact with water, fastening the eggs securely to the surface and to one another.

3. In the period of incubation the Arguli separate into three groups, one of which, represented by the two fresh-water forms, *foliaceus* and *catostomi*, requires thirty to thirty-five days before hatching. A second group, represented by the fresh-water form *americanus*, requires but fifteen to eighteen days, while the third group, represented by the fresh-water *stizostethii* and the salt-water *megalops*, remain in the egg from sixty to eighty days.

4. The emerging larvæ separate themselves into two groups corresponding, respectively, to the three short and the two long periods of incubation.

In the group which hatches in a month or less the nauplius, metanauplius, and early cyclops stages are passed inside the egg and the larva emerges in a later cyclops stage with all the appendages present, but many of them in a very rudimentary stage of development. Locomotion is effected by means of the second antennæ and a temporary pair of mandibular palps, both of which are elongated and tipped with long rowing setæ. Only the first pair of legs is at all developed, the others being mere immovable stumps. The first maxillipeds are not modified into sucking disks, but terminate in stout barbed hooks.



Reproductive organs are present and so far developed that the sex of the larva can be told at birth.

5. In the second group, which requires two months or over for incubation, the development of the larva inside the egg is carried still farther, so that it emerges not merely with all its appendages present, but with each fully developed, except the anterior maxillipeds, and all (even these) performing their appropriate functions. The swimming legs are sufficiently developed to be used exclusively for locomotion; the second antennæ are similar to those of the adult, and there are no temporary mandibular palps. The first maxillipeds and the rudimentary sexual organs are similar to those in the other group.

In these larvæ, therefore, there is no real metamorphosis after birth, since nothing but the first maxillipeds are at all changed in structure and even these serve the same function from the first.

6. By a series of molts at intervals of a few days the larva is gradually transformed into the adult. At the fourth molt, sixteen days after hatching, the sucking disks are so fully developed as to begin to function, and the sexual organs have matured, so that this molt is to be regarded as the close of the larval period.

#### MORPHOLOGY.

*Body regions.*—In consequence of the peculiar relations existing between the parts of the body in the Argulidæ we find different authors assigning entirely different names to them. This has been due in large measure to those modifications of the paired appendages resultant upon the parasitic habits of the animals, e. g., the hooks upon the anterior antennæ, the sucking disks upon the anterior maxillipeds, etc.

These modifications caused numerous mistakes in the early interpretations of the appendages, with corresponding mistakes in the body regions to which they are attached.

To Thorell (1864) and Claus (1875) more, perhaps, than to any other investigators are we indebted for the elimination of these errors, the scientific comparison of this group with others closely related to it, and its final establishment in its present position.

But both these authors worked with a very limited number of species. Claus's observations were confined to the two fresh-water species *foliaceus* and *coregoni*, and Thorell only added one other form, *purpureus*, which, however, was a parasite on salt-water fish. In view of such a meager supply of species upon which to base family characteristics, and the consequent doubt as to how fully they might have represented the entire family, it is hoped that the following comparative study of 13 American species, together with the comparative ontogeny which has preceded, may serve to supplement the data already given, and so strengthen Claus's assignment of the group.

The body of an Argulid divides itself naturally into three regions—

a cephalo-thorax, a free thorax, and an abdomen—the first and third being unsegmented, while the free thorax is divided into three well-defined segments. These regions thus correspond closely to those in the Eucepods. The anterior one has always been called the cephalo-thorax, but there has been considerable question as to how many segments of the thorax were fused with the head.

The answer to this question, and with it the solution of the whole problem of the body regions, the other two of which have received all the different names possible, rests entirely upon our interpretation of the two pairs of appendages which, in common with Claus and Thorell, we have designated as the anterior and posterior maxillipeds, but which are really the endopodite and exopodite of the posterior maxillæ, separated, and each joined to the body by an independent basipodite. If this latter statement be true, then of necessity only a single segment of the thorax is fused with the head. The free segments following must be the remainder of the thorax, and the unsegmented posterior portion is the abdomen. The only other supposition possible is that the appendages in question are anterior thoracic legs, which has been earnestly advocated by several authors.

If we can decide between these two alternatives, all the other problems will solve themselves.

First, then, the evidence in favor of regarding these appendages as anterior thoracic legs rests entirely upon their present form and function. But the value of such evidence must disappear the moment we reflect that these animals are parasites, for we have every reason to believe that both the form and the function of many appendages would of necessity be radically changed by long-continued parasitic habits.

In proof of this, witness the present form and function of the antennæ and mouth parts. Why may there not have been a similar change in the posterior maxillæ?

Again, the first pair of these appendages is placed so far forward that, if they are really thoracic legs, the mouth parts are entirely out of place for a crustacean, and particularly for one so closely related to the copepods.

Furthermore, if we are to look upon them as grasping or walking legs, it is evident that the appendages intervening between them and the mouth (i. e., the posterior maxillæ and the maxillipeds) have been suppressed, and that, too, so thoroughly that not a trace of them is left, even in early development.

But the appendages which do remain are perfectly developed, and such a complete suppression without assignable cause demands far better proof than mere present form and function.

The best argument, however, is derived from analogy. These two pairs of appendages correspond almost exactly in form, position, and

function with those called similarly maxillipeds in the Caligidæ. And since the habits of the two groups are alike we may reasonably assume that these similar appendages would correspond in origin and morphological significance.

But Claus has already proved that the so-called maxillipeds in at least a part of the Caligidæ (all the species in which he could prove anything) are the endopodite and exopodite, respectively, of the posterior maxillæ. Such being the case, we are compelled to regard these maxillipeds as similar in origin until definite proof can be obtained from their early development.

The three regions in an Argulid's body, therefore, are as we have already named them, a *cephalo-thorax*, in which only the anterior segment of the thorax is united with the head, a *free thorax* of three well-defined segments, and an *abdomen*, unsegmented and without appendages. The old name, "tail," has persistently clung to this posterior region, in spite of the fact that it contains the cloacal portion of the intestine, together with the testes in the male and the seminal pouches in the female.

The cephalothorax is much larger than both the other regions, and is developed into a broad horseshoe-shaped shield or carapace. This shield is strongly flattened dorsoventrally, but remains convex dorsally and concave ventrally like that of the horseshoe crab. Its sides (except in *A. elongatus*) are produced posteriorly into two broad, well-rounded lobes, in whose size and posterior reach we may find all gradations from those which barely cover the bases of the second pair of legs (*megalops. funduli, latus*) to others which reach back over the entire thorax and abdomen (*purpureus*), so that the carapace is the only thing visible in a dorsal view (see figs. 2, 12 (text), 24, 65).

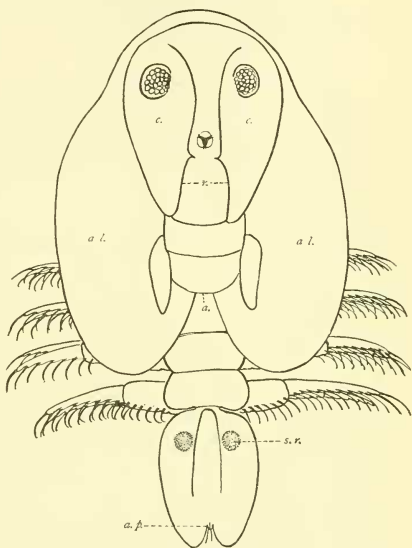


FIG. 12.—DORSAL VIEW OF ADULT ARGULUS MEGALOPS FEMALE. *a.*, JUNCTION OF CEPHALO—AND FREE THORAX; *al.*, ALE OR WINGS OF CARAPACE; *a. p.*, ANAL PAPILLE; *c.*, CEPHALIC AREA OF CARAPACE; *r.*, LONGITUDINAL CHITIN RODS; *s. r.*, SEMEN RECEPTACLES.

But however far back the lobes may extend, the sinus between them is always cut forward to the posterior border of the first thoracic segment, the one fused with the head. The base of this sinus, therefore, marks the division line between the cephalo and the free thorax (*a.*, fig. 12). The inner borders of the lobes are usually some distance apart, the sinus having a broad, more or less squarely truncated base. But sometimes it is so narrow that the lobes approach each other closely, and in alcoholic specimens may even overlap (*niger*, *aloxæ*, *americanus*).

These inner lobe borders may be parallel (*foliaceus*, *maculosus*) or may even converge posteriorly (*niger*, *catostomi*, *americanus*), but they usually diverge somewhat sharply, carrying the tips of the lobes away from the body (*megalops*, *laticauda*, etc.).

In its general shape or outline three types of carapace may be recognized, the *orbicular*, in which the width equals or exceeds the length (*catostomi*, *latus*, etc.), the *elliptical*, in which the length is considerably greater than the width (*foliaceus*, *laticauda*, *megalops*, etc.), and the *obcordate*, in which the greatest width of the carapace is nearer the posterior end (*americanus*, *purpureus*, etc.). It is a fact worthy of note here by reason of its important bearing upon the physiological function of the abdomen that species having a carapace of the first type have comparatively small abdomens, and in general the larger the carapace lobes the more restricted the abdomen.

In addition to the posterior sinus there is a broad, shallow lateral sinus on either side opposite the eyes.

At the base of this sinus a V-shaped portion of the carapace is quite clearly differentiated from surrounding portions by its greater thickness and perfect transparency (fig. 24). Both these differences are due to the fact that here the dorsal and ventral surfaces of the carapace approach each other until they come in actual contact and fuse together. From the points of the V's a narrow groove extends backward and inward on either side in a horseshoe-shaped curve, the toe of the shoe crossing the median line about where the anterior edge of the first or fused thoracic segment would naturally come (figs. 12 (text), 2, 6, etc.).

This groove divides the carapace into three regions—the cephalic or anterior oval region and the right and left lateral regions or *alæ* (*c.* and *al.*, fig. 12). Each region is capable of more or less independent motion, bending along the groove.

The cephalic region varies greatly in shape with the varying shape of the shield, being comparatively short and wide in those species which have an orbicular shield, while it is long and narrow in those whose shield is elongated.

Through its center longitudinally run two ribs formed by a thickening of the cuticular chitin (*v.*, fig. 12). These ribs start from the toe of the horseshoe and run forward toward the anterior margin. They first diverge slightly in a broad curve until they have passed the brain

and then curve inward toward each other, sometimes almost meeting at the median line, and finally diverge again toward the bases of the anterior antennæ.

Each one thus takes somewhat the shape of the old-fashioned letter *f*, the two letters being placed back to back. In *foliaceus* the anterior end of these ribs appears branched (Claus) as also in *salmini* (Kröyer), but this occurs in none of the North American species examined.

These long ribs are jointed once just behind the brain, to give the anterior region of the head greater freedom of motion.

They are also connected with each other, posterior to the joints, by several cross ribs, the first of which is close to the joints and quite concave toward the brain.

In some species (*niger*, *foliaceus*, *funduli*) these cross ribs give the appearance of vertebrae, especially in alcoholic specimens, as noted by Claus, but they are practically invisible in the living animal by reason of their transparency, as can be seen in the photographs. Other stout branch ribs extend radially outward from the mid-line toward the lateral margin, the largest and most conspicuous pair being situated between the posterior maxillipeds and the anterior swimming legs (figs. 14, etc.).

In addition to these ribs there are two oval chitinous rings in each lateral ala at some little distance from the margin.

The anterior one is short, often triangular, and situated about opposite the mouth, while the other is much larger and longer and reaches nearly the entire length of the lateral area.

The shape and arrangement of these lateral rings is peculiar for each species and affords a very reliable secondary specific character, as will be readily seen by comparing any two of the figures showing the ventral surface.

The free thorax has a flattened conical form, the segments diminishing in size from in front backward. The posterior segment is triangular in outline, the apex of the triangle terminating posteriorly on the ventral surface at the opening of the oviduct or the vas deferens. On the dorsal surface this posterior segment is usually more or less overlapped by the abdomen. Each segment, including the one fused with the head, carries a pair of swimming legs, the posterior pair pointing obliquely backward in consequence of the oblique sides of the segment which carries them. In alcoholic specimens these posterior legs are often curled in and wholly covered by the abdomen. (See figure of *A. niger*.) The thorax has no other appendages save in *purpureus*, where there are two scale-like lobes attached to the posterior segment on the ventral surface and projecting backward beneath the abdomen (fig. 65).

The latter is much thinner than either of the other two body regions. It consists of little more than two plate-like lobes or lamellæ, filled

with blood sinuses and carrying in their thickened bases the testes in the male and the seminal receptacles in the female. Through the center runs the much-narrowed cloacal portion of the intestine and around this are longitudinal muscles which assist in circulation (p. 669).

The outline of the abdomen is usually oval or broadly triangular. In some species whose cephalothorax is orbicular the abdomen also approaches closely to that shape (*catostomi*). In other species (*lati-cauda*, etc.) it is broadened posteriorly until it becomes almost perfectly elliptical. Its size and shape differ greatly in the two sexes even of the same species. The presence of the long testes elongates the lobes until sometimes the abdomen of the male is nearly twice as long as that of the female (*funduli*).

It is always much longer, and thus produces a narrowed elliptical form, with a tendency toward acumination in the lobes posteriorly. On the other hand, the spherical seminal receptacles of the female are situated far forward in the lobes and tend to widen that portion especially, producing a broad triangular form, usually with blunt, rounded tips.

The abdomen is cut posteriorly by a median sinus which runs forward between the lobes very varying distances in the different species. It may be broad, shallow, and well rounded (*catostomi*), broadly triangular (*maculosus*, *lepidostei*), narrowly triangular and cut deeply (*stizostethii*, *niger*), or so narrow as to be slit-like (*versicolor*).

The anus is situated at the base of the sinus, and somewhere along the sides or at the base are to be found the anal papillæ.

The position of these papillæ as subterminal, lateral, or basal adds another secondary specific character which is very useful in classification.

*The appendages.*—On the ventral surface of the carapace we find the cephalic and the first thoracic paired appendages, and along the median line the sting and the mouth apparatus.

The two pairs of antennæ are situated in front of the eyes and lie in shallow troughs or depressions in the ventral surface of the carapace. The first antennæ have a broad flat basal portion which is two-jointed; the proximal joint is much the smaller of the two, triangular in shape, and is prolonged backward into a stout blunt chitinous spine.

The distal joint is considerably elongated at right angles to the proximal one (and hence at right angles to the central axis), and it terminates in a strong sickle-shaped hook which is curved over ventrally. There is usually a similar but much smaller hook upon the anterior margin near the base of the joint, and in most species a stout spine, occasionally two of them (*versicolor*), upon the posterior margin.

The terminal portion of the antenna which is three-jointed is so diminished in size and relatively so insignificant as to be easily overlooked. Furthermore, it is fastened to the distal joint alongside the

huge chitinous hook and in some species (*laticauda*) does not reach beyond the latter.

The larval development shows that this prehension which so predominates in the adult is really acquired and that the antennæ are originally tactile.

The second antennæ have retained this original function in greater measure than the first. They consist of a stout cylindrical basal portion, which is also produced backward near the median line into a blunt chitin spine similar to that on the first antennæ and right in line behind it.

Sometimes this spine is reenforced by another situated just anterior to it, the two and the spine on the proximal basal joint of the first antenna forming a row alongside the median line (*maculosus*, *americanus*). The remaining three joints of these second antennæ are much narrower than the basal one and the terminal joint is also very short. They are all, including the basal joint, armed with a few bristles on their anterior surfaces at the distal ends. The three terminal joints are usually flexed posteriorly until they form a right angle with the basal joint.

The anterior maxillipeds in all adult Arguli are modified into sucking disks. This also, as can be seen from the ontogeny, is a derived or acquired character.

The function of prehension is of course the same whether the appendage end in a claw or a sucking disk, but with the growth of the disk comes a secondary function of walking or scuttling about over the surface of the fish's body. For this the disk is much better suited than a terminal claw; the latter gives as firm a hold when once fixed in the fish's skin, but does not admit of adjustment rapid enough to be used as an organ of locomotion. These disks consist of a short cylindrical basal portion, representing the basal joint of the original larval appendage, and a terminal border of nearly twice the diameter.

The latter does not represent the terminal joints of the original appendage, but seems to be a new growth after the absorption of those joints. In the larval development these joints persist for a long time as a useless appendage attached to the side of the maxilliped between the base and the border, and they seem to be gradually absorbed and used in making the border, much as the tadpole's tail is used to make the hind legs of the little frog. The border is largely membraneous, is serrated around the edge, and is strengthened by numerous rays which

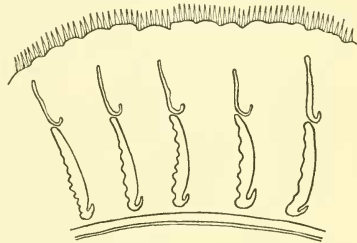


FIG. 13.—BORDER OF SUCKING DISK IN ARGULUS AMERICANUS.

are formed in a very different manner in the various species. In *foliaceus* they consist of a row of chitin joints so short as to appear spherical or slightly elliptical (Claus). In *americanus* they consist of two concentric rows of chitin rods, each of which is shaped like the letter J (fig. 13).

The rods in the outer row are much smaller than those in the inner one, and they do not reach nearly to the edge of the membrane. In *megalops* the rays are made up of a series of trough or gutter shaped plates overlapping one another like shingles (fig. 14).

The base of the membrane is strengthened by three chitin rings, the basal one of which is large enough to hold its shape perfectly against the contraction of the muscles.

The terminal one serves as a support for the rays and to it their proximal ends are attached. This border contains two sets of muscles, circular and radial, by which it can be elevated till it assumes the same direction as the cylindrical base and simply forms a hollow terminal portion to the latter, or it can be depressed till it stands out at right angles to the base like the

brim of a hat. It often assumes the first position on fixation, but the last one is the normal posture in the living animal. Its membranous structure, strengthened by the chitin rays, with the flexibility produced by the joints in the latter, and the serrated edge, enable it to fit down snugly to the rough surface of the fish's body



FIG. 14.—BORDER OF SUCKING DISK IN ARGULUS MEGALOPS.

and produce a tight joint. The lumen of the base is nearly filled by four large muscles arranged in pairs, approximately right and left and anterior and posterior. By the contraction of these muscles a partial vacuum is formed inside the base and the flexible border is securely fastened to the surface on which it rests. The simple relaxation of the muscles restores the original lumen and the disk is detached.

By relaxing its hold with one disk and carrying it forward while the other remains fastened the animal moves about with surprising rapidity. Not only is Thorell wrong when he says (1864) that these appendages are "used exclusively as fixing organs," but it seems highly probable that they have been modified into this disk form for the express purpose of functioning as locomotor organs. And while the function of fixation may, and probably does, still take precedence, yet that of locomotion becomes a close second. The relative size of these disks varies greatly; in some species (*funduli, latus*) it reaches nearly a third the width of the carapace, and be it remembered these are forms in which the carapace is orbicular. In others (*laticauda, megalops*) it is not more than a sixth or a seventh of that width.



The second maxillipeds retain more of their original shape. They consist of a short basal segment and four longer terminal ones. The ventral surface of all these segments, over the whole or a part of its area, is raised up into rough papillæ, or armed with spines and bristles pointing backward.

In addition the basal segment has on its ventral surface a raised area, often armed with spines or bristles. This area projects posteriorly beyond the border of the joint, and in all species examined except one (*latus*) is produced into three strong teeth. For this reason it was designated by Kröyer as the "kammen" (pecten or comb). In many species (*lepidostei*, etc.) these teeth are long and very sharp, while in others they take on more of the nature of plates, being broad and squarely truncated or only a trifle rounded posteriorly (*laticaula*, *catostomi*). The terminal segments of these appendages are armed with two claws and a third process or papilla, often ending in a spine. (Plates X, XII, XXI.)

With reference to the use of these appendages, it is at once evident from the spines, teeth, and rough areas on their ventral surfaces that they serve to keep the Argulus from slipping backward on its host, and that this must be their chief function.

Such an interpretation is strengthened by the fact that in those species which have the spines and hooks of the antennæ and the ventral surface of the carapace particularly well developed (*maculosus*, *americanus*, etc.) the posterior maxillipeds are comparatively small and poorly armed.

On the contrary, species like *catostomi* and *alosse*, where the spines on the antennæ are weak and insignificant, the posterior maxillipeds are large, stout, and well armed. There is thus in every species examined quite a uniform balance between the size and armature of these posterior maxillipeds and that of the antennæ and carapace.

That these appendages may also be used for "cleaning the sucking cups and for removing extraneous particles from the cavity," as maintained by Vogt (1845), seems very likely from the forceps nature of the claws on the terminal joint, but the present author has never had the good fortune to actually witness such an operation. That they "serve principally as organs of locomotion and may therefore be called creeping feet (*pedes gessorii*), as they have, indeed, been named by Kröyer" (Thorell), does not seem probable either from their structure or their development. And in the scores of living Arguli which have been carefully watched no such use of these appendages has ever been detected.

The four pairs of thoracic appendages are swimming feet and are the principal organs of locomotion. They each consist of a two-jointed basipod and an exopod and endopod, of which the former is slightly the longer. The joints of the basipods on the several pairs of legs

show a regular gradation in length, the proximal ones diminishing and the distal ones increasing, from in front backward. The proximal joints of the posterior pair of legs are usually triangular in shape to fit the sides of the triangular posterior thoracic segment.

They are also produced posteriorly into lobes more or less boot-shaped, with the toes turned outward. In some species (*maculosus*, *versicolor*, *lepidostei*), these lobes are as large as or even larger than the joints themselves.

In the female all the other basipod joints (except the posterior) are simple and without appendages, but in the male the two posterior pairs of legs in all species, and in some the three posterior pairs, carry accessory sexual organs upon their basipods. These will be described more fully later. The endopodites of the first pair of legs are three-jointed, the basal joint including the larger part, while the two terminal joints are very small and short. The latter do not carry setae like the basal joint, and they terminate in a pair of forceps-like spines.

The endopods of the second pair of legs are not jointed; those of the third and fourth pairs are jointed once near their center. The exopods in all four pairs of legs are *without joints*. Kröyer, Vogt, and Leydig were deceived by the swollen bases of the large rowing setae into declaring that both exopods and endopods were many jointed, and this error has been religiously preserved down to the very latest text-books.

Lang distinctly says that the exopods and endopods in the Argulidæ "are long and many jointed."<sup>1</sup> Parker and Haswell do not make any statement, but Claus's figure, which they publish, shows many joints.

This figure was drawn by Claus to show the development of the testes and the sucking disks on the anterior maxillipeds, and he has slurred over many of the other details. That he did not intend to represent the endopods and exopods as actually jointed is abundantly manifest from enlarged detailed drawings of the three posterior legs of the male (the figure in question is also that of a young male), in which they are represented correctly as without joints, save for the single middle joint in the endopod of the two posterior legs. Furthermore, he distinctly says, in the text accompanying these figures,<sup>2</sup> that "in the place of numerous joints capable of independent motion, there are only joint-like breaks or intervals apparent in the hair-like foot branches."

This is certainly the condition in every American species examined, as is readily proved by reference to the musculature.

In all the exopods and in the two anterior endopods there is a single unbroken muscle strand running from base to tip. In the two posterior endopods this strand is broken at the central joint, as are the muscles everywhere else at joints in all the appendages (fig. 15). It is

<sup>1</sup>Part I, p. 316, English translation.

<sup>2</sup>Edition of 1875, figs. 44, 45, and text, p. 250.

unfortunate that Claus's figure should have become the classic for all text-books, encyclopedias, and dictionaries. It does not show any of the segmentation in the swimming legs correctly, and without the accompanying text manifestly places its author in error.

Both exopods and endopods are furnished with two rows of long plumose setæ along the dorsal and ventral edges of their posterior surface, which render them efficient oars for propulsion through the water. Similar shorter setæ are found along the posterior border of both basipod joints of the posterior legs, and in some species (*maculosus*, *versicolor*, etc.) along the basipods of all the legs. Often, also, the entire surface of the boot-shaped appendages of the basal joints of the posterior legs will be found covered with these setæ.

More than half the species (17 out of 26) have an appendage called a flagellum (*Geißelanhang*) attached to the two anterior pairs of legs. This consists of a slender shaft attached to the distal end of the basi-

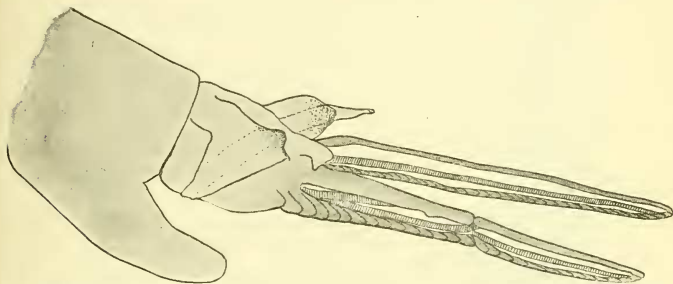


FIG. 15.—POSTERIOR SWIMMING LEG OF ARGULUS AMERICANUS; THE ARRANGEMENT OF THE MUSCLES SHOWS CONCLUSIVELY THAT THE EXOPODITE IS NOT JOINTED, AND THAT THE ENDOPODITE HAS BUT A SINGLE JOINT.

pod, just above the base of the endopod. At first it is directed outward parallel to the endopod, but is bent abruptly upward and inward, so that it lies along the dorsal surface of the basipod.

It also carries two rows of plumose setæ and is capable of independent motion. There can be little doubt that one at least of its functions is to keep the ventral surface of the carapace clean and to remove any foreign particles that might find lodgment between the legs and carapace. The blood enters the main shaft of these flagella just as it does the exopods and endopods of the swimming legs, but can not of course get out into the setæ. This coupled with its very small size renders it difficult to see how such an appendage can serve any important respiratory function.

In the females of many species we find a pair of long finger-like papillæ, situated one on either side of the opening of the oviduct between the bases of the posterior pair of legs.

These are manifestly tactile organs and assist in placing the eggs during egg laying. They are never found on males.

The abdomen has no appendages nor any trace of them at any stage in its development.

*The digestive system.*—The mouth parts consist of two separate organs united at their bases. The anterior portion has been called, respectively, a “sting,” a “gadd,” and a “sucker” by various authors. The first of these names is the most applicable. This sting is a long,

very sharp-pointed spine, tipped with chitin and inclosed in a sheath of the same material, to which it is so attached that it can be extended and withdrawn like the finger of a glove. When not in use, it is partly withdrawn and lies in a longitudinal groove which runs forward between the bases of the antennæ. It is a veritable sting, for the spine is hollow and its lumen serves as the duct of a poison gland situated at the base of the sheath.

The inner portion of the sting is soft and flexible and is folded upon itself when withdrawn. It is forked near the base of the sheath and a branch of the duct passes out to the poison gland on either side (fig. 16).

When wished for use, the sting is dropped down from its groove upon the fish's skin, into which it is then pushed by eversion.

Thus in the way in which it is carried and used the sting bears considerable resemblance to the proboscis in certain hemiptera. Its chief use appears to be that of puncturing the skin and securing a strong flow of

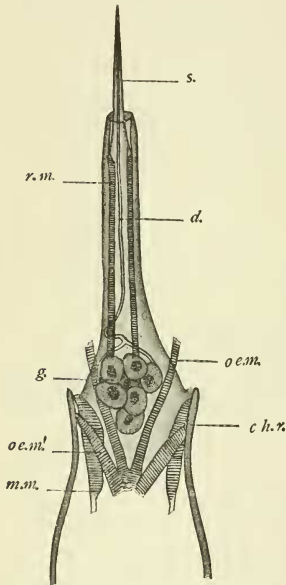


FIG. 16.—STING AND POISON GLAND OF ARGULUS VERSICOLOR. *ch. r.*, CHITIN RIB OF PROBOSCIS; *g.*, POISON GLAND; *d.*, DUCT OF POISON GLAND; *mm.*, MANDIBLE MUSCLES; *oc. m.*, OESOPHAGUS MUSCLE; *oc. m'.*, SIDE MUSCLE OF OESOPHAGUS; *r. m.*, RETRACTOR MUSCLE; *s.*, STING.

blood both by its wound and also the irritation caused by the pouring in of the secretion from the gland.

The posterior portion of the mouth apparatus is the proboscis; it also is cylindrical and can be elevated or depressed at pleasure. But it is much larger in diameter than the sting and is somewhat club-shaped at the free end. When not in use, there is a groove extending back between the bases of the two pairs of maxillipeds in which it is carried.

The walls of the proboscis are formed of an upper and an under lip, respectively, which are held in place and at the same time rendered flexible by a jointed chitin framework.

The latter can be seen on either side of the proboscis tube as a series of longitudinal ribs, forked at their distal ends, where they are united to one another and to a transverse framework which bounds the oral aperture and gives support to the mandibles and maxillæ. The pattern of this framework, as well as the details of the mandibles and maxillæ, varies greatly in different species, but the essential features are the same in all, and are as follows:

The under lip forms the posterior surface of the tube and spreads down over the hood-shaped end and up a very little way on the anterior side, terminating in the shape of a half-moon around the lower border of the mouth aperture (fig. 17).

At either side this half-moon is prolonged into a triangular flap which projects upward over the outer surface of the upper lip, and must hence be regarded as a rudimentary labial palp (*l. p.*).

The remainder of the ventral surface is formed by the upper lip, which terminates at the mouth in a somewhat squarely truncated (*americanus*, *catostomi*) or even emarginate (*niger*, *megalops*) lip proper, projecting into the concavity of the under lip.

In *foliaceus*, in addition to the transverse opening at the end of the proboscis, there is a narrow, somewhat lance-shaped longitudinal slit extending along the anterior surface toward the base of the proboscis. This slit is considerably longer than the transverse opening, and its edges are sharply serrated where it merges into the latter.

Hence the mouth opening has an elongated triangular form in *foliaceus*. But in *catostomi* the longitudinal slit is very much shorter than

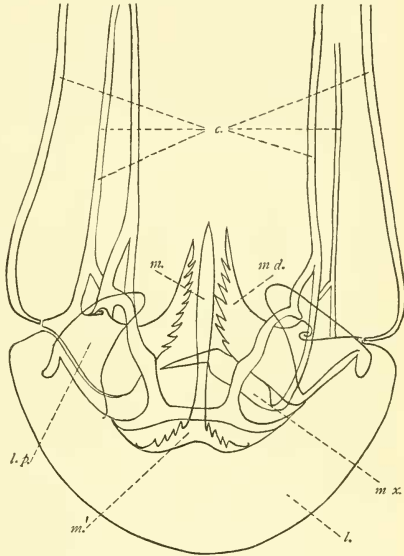


FIG. 17.—MOUTH-PARTS AND CHITIN SKELETON OF PROBOSCIS OF ARGULUS FOLIACEUS (AFTER CLAUS). *c.*, CHITIN FRAMEWORK; *l.*, LOWER LIP; *l. p.*, LABIAL PALP; *m.* AND *m'*, LONGITUDINAL AND TRANSVERSE PORTIONS OF THE MOUTH OPENING; *m d.*, MANDIBLE; *m. x.*, MAXILLA. (COMPARE WITH FIG. 8.)

the transverse one, in fact is little more than a notch in the upper lip, though its edges are still serrated like those of *foliaceus*. In many of the other species (*niger*, *megalops*, etc.) the longitudinal slit disappears entirely, leaving a curved mouth opening transverse to the long diameter of the proboscis tube and often slightly enlarged at either end. In these forms also there is no serration of the edges of the mouth opening. Just behind the labial palps on either side the chitin framework is thickened somewhat where the longitudinal ribs join the transverse rods, and to these thickened joints are attached the mandibles and maxilla.

The mandibles (*md.*) are elongated, somewhat triangular or broadly sickle-shaped chitin plates, which curve inward and upward toward each other so that their pointed and toothed tips almost meet in the mid line of the gullet above the mouth opening.

They are always bordered by sharp-cutting teeth on their inner margins, and sometimes (*americanus*, etc.) along the outer margins also, and are evidently designed to cut and tear the flesh of the parasite's host and so stimulate the flow of blood. The two maxilla (*mx.*), for there is but a single pair, are also thin chitinous plates of various shapes, which are attached at the same place as the mandibles, but which extend backward and outward behind the mandibles nearly parallel with each other. They are sometimes toothed on their inner margins (Thorell), but are usually smooth and terminate in a long sharp spine, which also is evidently used to stimulate the flow of blood from the host.

The proximal end of the proboscis passes directly into the short œsophagus, which in turn opens into the stomach.

These portions of the digestive system are the same in the adult as in the larva and do not need to be described again here.

The only thing to be added is that the side pouches of the stomach become more and more branched with age until finally they are entirely broken up into ramifications, as is well shown in the photograph of *americanus* (fig. 84).

*The circulatory system.*—There is a well-defined heart and a short aorta which opens directly into the body cavity, but there are no other blood vessels of any sort. Instead, the blood circulates about freely through the lacunæ and sinuses, which form a network all over the body, as already described (p. 669).

The blood itself is a colorless liquid in which float numerous corpuscles. The latter are smooth, spindle, or pear-shaped, and occasionally somewhat fibrous at the ends.

As soon as the circulation stops they sink to the bottom, but they do not become spherical in any American species so long as the animal remains alive. They contain a well-defined nucleus, which can be brought out clearly by the addition of a little acetic acid (Leydig).

The heart lies in the median line of the body, just beneath the skin of the dorsal surface. It is triangular in outline, the base of the triangle extending squarely across the thorax at its junction with the abdomen. The apex of the triangle passes directly into a long cylindrical aorta, which reaches forward, diminishing gradually in size, to the brain, under which it opens into the cœlom. The walls of both heart and aorta are well supplied with striated muscle fibers by whose contraction a rhythmic pulsation is produced.

Jurine (1806), Leydig (1850), and Claus (1875), have each described in some detail the course of the blood currents in *foliaceus*, and the present author has observed them in the three American species, *versicolor*, *americanus*, and *catostomi*.

Of these species the course of the blood in *versicolor* and *catostomi* corresponds quite closely with that given for *foliaceus*, but in *americanus* it is quite different in several details.

In the former species the heart has six openings; of these two are median and four are paired at the sides (Claus, fig. 37).

One of the median openings is anterior and passes into and through the aorta and out into the cœlom under the brain. The other is posterior and opens backward through the ventral part of the base of the triangle into the sinus around the cloaca.

Of the paired openings the anterior pair are ventral and consist of a diagonal slit on either side just at the base of the aorta. The posterior pair are lateral and open out of the basal angles of the triangle into the broad sinus which follows the edge of the abdomen. These lateral paired openings and the posterior median opening are guarded by valves, but the other three open and close by the simple approximation and separation of the edges of the slits.

The heart pulsates about once a second and drives the blood out through the aorta. This stream almost immediately divides, portions going to the right and left and bathing the tissues of the head and antennæ, and especially the eyes, which are entirely surrounded by a wide sinus. Another portion turns downward into the common base of the proboscis and sting and there separates, a part going forward into the sheath which surrounds the sting and a part backward into the proboscis.

All these anterior streams turn back on either side to the bases of the anterior maxillipeds. A part enters the maxillipeds themselves, a part keeps on posteriorly, passing the bases of the swimming legs and sending out currents to each, and the remainder turns out sidewise into the lateral areas of the carapace. Here it percolates through the lacunæ, between and around the numerous stomach ramifications, gradually working its way back in broad curves to the two central side streams, which finally enter the heart by the ventral unguarded slits.

At every pulsation also a portion of the blood is driven backward through the posterior median opening into the sinus around the cloaca. The bulk of this stream passes directly back to the anus where it divides, a half passing around the wide sinus on the border of each lobe of the abdomen.

But portions of the central cloacal stream are given off sidewise all the way back to the anus: these percolate through the sinuses and lacunæ and around the sexual organs of either lobe and finally join the returning streams along either margin and enter the heart through the posterior valved lateral openings.

In this way a constant interchange of the blood from various parts of the body is maintained, and that portion of it which percolates through the lateral areas of the carapace and the lobes of the abdomen is thoroughly purified during its passage.

The circulation in *americanus* differs in several particulars; there are but five openings in the heart, the ventral one consisting of a single median longitudinal slit instead of paired lateral ones (fig. 18). All the blood enters through the lateral valved openings *a*; a part of it passes out of the aorta anteriorly *b* and another part out of the posterior median aperture *d*, and each of these streams follows the same course as in *foliaceus*. But the greater bulk turns downward and passes out of the median ventral slit (*c*). This stream pours around the intestine and separates naturally into two side streams, running forward past the bases of the swimming legs, sending

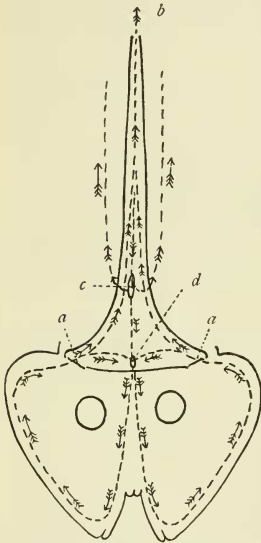


FIG. 18.—DORSAL VIEW OF THE HEART OF ARGULUS AMERICANUS (DIAGRAMMATIC). *a*, PAIRED LATERAL OPENINGS; *b*, ANTERIOR OPENING OF AORTA; *c*, ANTERIOR, AND *d*, POSTERIOR VENTRAL OPENING.

out lateral streams into each of them, and joining the anterior streams from the aorta underneath the brain. On its return the blood percolates through the lateral sinuses of the carapace and, joining the streams from the borders of the abdomen, enters the openings at the sides of the triangular base of the heart. (See also fig. 19.)

This circulation does not depend for its impetus upon the pulsation of the heart alone. It is helped, as such lacunal circulation must always be, by the contraction of muscles in various parts of the body. Especially is this true of those muscles which contract somewhat rhythmically, like the muscles of the stomach and intestine in their peristaltic movements, and of the legs in swimming. There is also a



network of longitudinal muscles around and over the cloaca which keeps up a rhythmic contraction that greatly assists circulation.

These have already been mentioned as one of the chief agents in the larval circulation prior to the development of the heart, and they seem to retain their function in the adult.

*Respiration* has been already fully discussed in the larva, and there is nothing to be added here. It may be well to repeat that respiration is integumental, and that it is not confined exclusively to the abdomen. The lobes of the carapace have a respiratory function as important as that of the abdomen, and become the chief centers for blood purification in those species (*catostomi*, etc.) whose abdomen is comparatively very small.

*The nervous system* is well developed, and consists of a dorsal brain connected with a ventral chain of ganglia, and nerves running to the various appendages. The brain consists of two portions, each of which is lobed (fig. 20). The upper part is situated just beneath the skin on the dorsal midline of the carapace, right over the common base of the mouth and sting. Its three lobes have an outline and arrange-

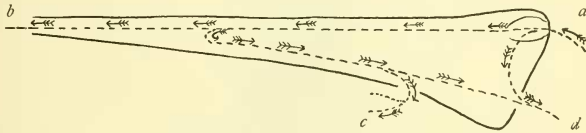


FIG. 19.—SIDE VIEW OF THE HEART OF ARGULUS AMERICANUS (DIAGRAMMATIC). (FOR LETTERING SEE FIG. 18.)

ment similar to that of the parts of a clover leaf. The outer rounded portions are almost transparent, but the inner borders, where the three come in contact, are heavily pigmented, and show through very prominently as a dark brown, almost black, triangular spot. The under part is much larger than the upper, is more oval or elliptical in shape, and extends some distance in front of the pigment spot. It is divided along its longitudinal or antero-posterior diameter into two lobes, each of which passes insensibly at the anterior end into a thick nerve running to the eye on that side. In most species these optic nerves have a good-sized swelling, the optic ganglion, on their outer borders just before reaching the eyes.

The posterior ends of the lobes also pass insensibly into thick-set commissures, which curve around the oesophagus on either side and connect with the interior ventral ganglion.

At the point where they leave the lobes there is a considerable swelling, the "*schlundganglion*" (Claus). From this swelling a nerve runs forward to the posterior antennæ. There is also another nerve leading to the anterior antennæ from some portion of this ventral part of the brain, but I have been unable to locate it any more exactly than Claus.

The ventral chain consists of six ganglia placed so near together that they are almost completely fused. But they can still be distinguished clearly by the transverse grooves and constrictions between them (fig. 20). They diminish in size from in front backward, the anterior one being about twice the diameter of the posterior. From the anterior ganglion a stout nerve (there are several others leading from

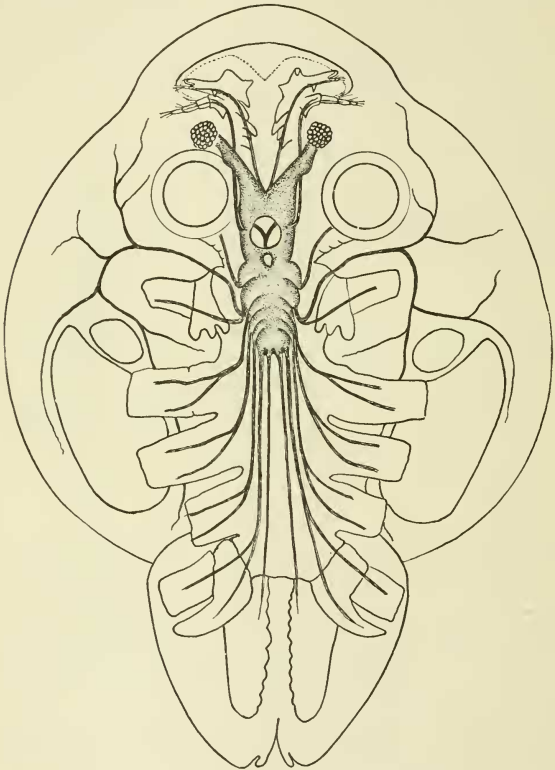


FIG. 20.—THE NERVOUS SYSTEM OF ARGULUS AMERICANUS.

the same ganglion in *coregoni* according to Claus's figure) is given off on either side which divides quickly, the anterior branch innervating the mouth parts, while the posterior branch passes out into the carapace. Another stout nerve is given off usually from the second ganglion<sup>1</sup> which divides and innervates the two pairs of maxillipeds.

<sup>1</sup> Leydig states that this nerve comes from the first ganglion in *foliaceus*. Claus gives it from the second ganglion in *coregoni*, an arrangement which exists, also in *americanus* and *versicolor*. It has not yet been located in other species.

From each of the other ganglia is given off a pair of nerves (two pairs in *coregoni*) which run diagonally backward and innervate the swimming legs in order. From the posterior ganglion two pairs of nerves in the American species and *foliaceus*, and three in *coregoni*, run directly backward along the ventral wall of the intestine. The outer of these two pairs goes to the posterior swimming legs; the inner one runs into the abdomen and innervates its muscles, together with those of the heart. Especially worthy of notice are the innerva-

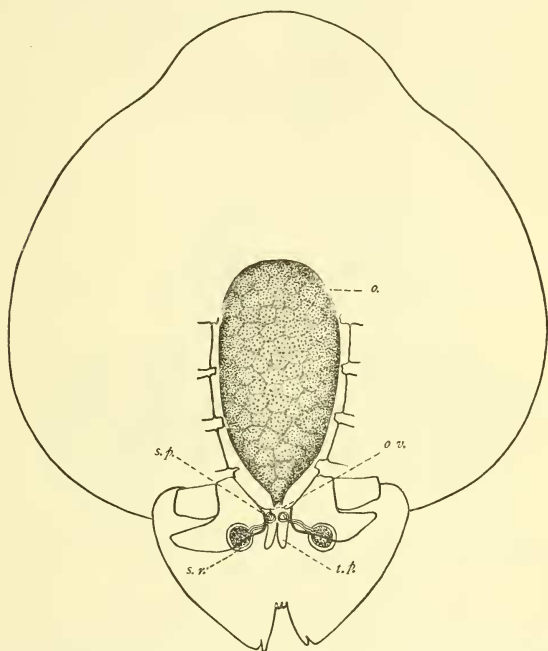


FIG. 21.—FEMALE SEXUAL ORGANS OF ARGULUS AMERICANUS. *o.*, OVARY; *ov.*, OVIDUCT; *s. p.*, SEMEN PAPILLE; *s. r.*, SEMEN RECEPTACLE; *t. p.*, TACTILE PAPILLE AT THE OPENING OF THE OVIDUCT.

tions of the basal lobes of the posterior swimming legs, which are used as tactile organs in egg laying, as already described, the innervation of the accessory sexual organs on the swimming legs in the male, and that of the tactile papillæ on either side of the opening of the oviduct in the female.

For sense organs the Arguli possess only eyes and tactile organs. The eyes are large in most species and are made up of 30 to 60 facets, spherical or ellipsoidal in form, but packed so closely together as to become more or less angular. The outer portions of these facets are free from pigment, but the inner portions are heavily pigmented.

The whole eye is usually spherical, but in a few species is somewhat elongated diagonally or crescent shaped.

Each eye is surrounded by a wide blood sinus through which the blood constantly flows, so that the eyes are continually bathed in it. The eyes are capable of moving inside these sinuses and often show a trembling motion similar to that in other copepods.

The tactile organs include the two pairs of antennæ, the original tactile function of the first pair being almost wholly superseded by the acquired function of prehension, the basal lobes on the posterior legs, and the long finger papillæ beside the opening of the oviduct in the female. There are also tactile setæ around the anterior half of the edge of the carapace, and some at least of the accessory organs in the male serve primarily as organs of touch (p. 697).

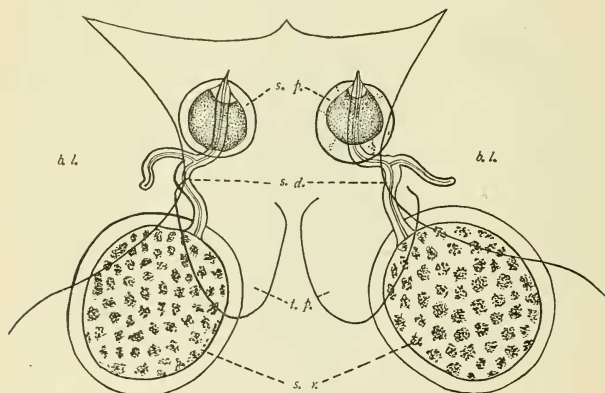


FIG. 22.—SEMEN RECEPTACLES AND PAPILLÆ OF ARGULUS AMERICANUS FEMALE UNDER GREATER ENLARGEMENT. *b. l.*, BASAL LOBES OF POSTERIOR LEGS; *s. d.*, DUCTS LEADING FROM THE RECEPTACLES TO THE PAPILLÆ; *s. p.*, SEMEN PAPILLÆ; *s. r.*, SEMEN RECEPTACLES; *t. p.*, TACTILE PAPILLÆ.

*The sexual organs.*—The sexes are separate, and the female is usually larger than the male, though there is no such difference in size as among some of the other parasitic forms. And in *laticauda* the males are actually larger than any females thus far found. The females are also considerably more numerous than the males.

The female sexual organs consist of an unpaired median ovary and paired seminal receptacles (fig. 21). The ovary starts as an unpaired ridge of cells along the right or left side of the intestine. In later development it migrates to the median line, and becomes a simple receptacle for holding the maturing eggs. It reaches from the stomach to the posterior end of the thorax, where it narrows abruptly into a short oviduct which opens out at the base of the sinus between the lobes of the posterior legs. In many species there is a long tactile

papilla on either side of this external opening, but some are without it. The walls of the ovary are muscular, and in most species exhibit peristaltic movements similar to those in the intestine. In some species the dorsal surface is beset with dark brown pigment spots, arranged in somewhat regular longitudinal rows. The eggs are spherical when first formed, and are each developed inside a small petioled bag, so that the whole mass takes on the appearance of a bunch of grapes.

As they grow they become ellipsoidal, and are finally packed together so tightly as to become angular. Between the egg and the membrane of the bag in which it is contained is a clear, jelly-like substance which forms a sort of shell around the egg. The semen receptacles are dark-colored spherical capsules lying in the anterior portion of the abdomen lobes near the cloaca (fig. 22). From each capsule a duct (*s. d.*) runs forward and inward to a hollow conical papilla (*s. p.*) situated nearer the midline on the ventral surface. This papilla is in the anterior end of an elliptical shield composed of several chitin plates, which covers the ventral surface of the abdomen around the papilla and holds it securely in place. Near the center of the duct is a blind appendage. The papillæ are strongly curved over inward toward the midline, and both they and the shield plates are capable of motion.

The outer end of the semen duct leading from the capsules fits into the papilla as into a sheath and can be withdrawn or extruded at will. Its tip is contracted and hardened into a sharp chitinous spine, and when extruded this spine projects from the tip of the papilla and comes in contact with the egg as the latter issues from the oviduct. When withdrawn the papilla is closed and the semen is confined to the receptacle and the proximal part of the duct.

Claus calls attention to the thickness of the eggshell and the consequent necessity of a micropyle through which the sperm may enter the egg. But he states that careful examination does not reveal any micropyle, and gives it as his opinion that the sharp chitin spine at the tip of the duct just noticed pierces the egg shell and makes thus a passage for the sperm.

However this may be, it is certain that the egg as it issues from the oviduct, and is grasped between the bases of the posterior legs and carried back into place on the underlying surface, must come forcibly in contact with this spine and receive from it a discharge of sperm.

The male sexual organs may be distinguished first as essential and accessory. The essential organs include the testes, an unpaired seminal receptacle, the ducts leading from the testes to the receptacle and from the receptacle to the sexual opening, and a pair of blind capsules connected with the latter ducts (fig. 23). The testes are situated in the lobes of the abdomen in a position corresponding to that of the

seminal receptacles in the female. They are much larger than the receptacles, however, and as a result the abdomen of the male is comparatively larger and longer than that of the female of the same species. The testes (*t.*) are ovoid or ellipsoidal in shape, and in nearly every species are covered on the dorsal surface with dark pigment spots corresponding to those on the dorsal surface of the ovary. From the

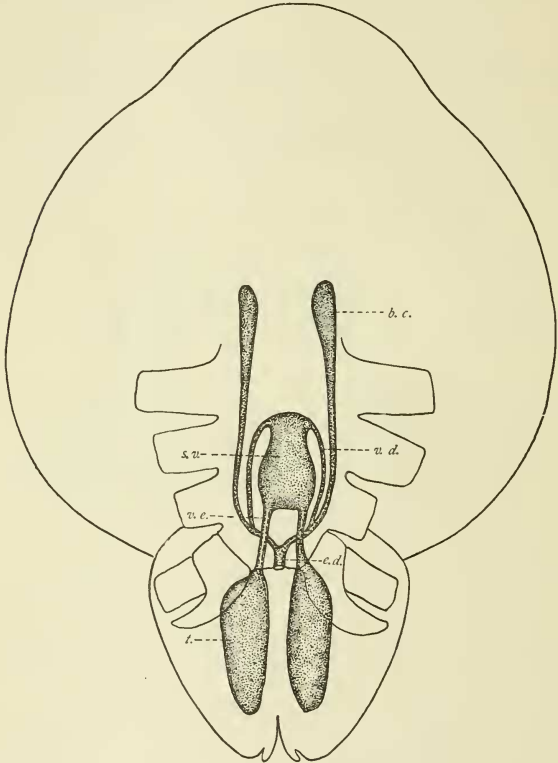


FIG. 23.—MALE SEXUAL ORGANS OF ARGULUS AMERICANUS. *b. c.*, BLIND CAPSULE; *e. d.*, EJACULATORY DUCT; *s. v.*, SEMEN VESICLE; *t.*, TESTIS; *v. d.*, VAS DEFERENS; *v. e.*, VAS EFFERENS.

anterior end of each testis there runs a duct, the vas efferens (*v. e.*), which leads forward to the unpaired seminal receptacle or vesicle (*s. v.*) lying in the posterior thorax on the midline, above the intestine.

The vasa efferentia enter the vesicle at its posterior end. From the anterior end there is given off on either side another duct, the vas deferens (*v. d.*), which turns backward alongside the vas efferens until

it reaches the posterior border of the thorax, where it turns downward and inward, meeting the corresponding duct from the other side on the midventral line and fusing in a very short, common ejaculatory duct (*e. d.*) which opens at the base of the sinus, between the lobes of the posterior legs, thus corresponding exactly to the opening of the oviduct in the female. Connected with the vasa deferentia on either side, just where they turn down to meet each other, is a pair of accessory blind capsules (*b. c.*). These are long and slender, and reach forward far beyond the seminal vesicle and are somewhat enlarged at their anterior ends so as to be club-shaped. All the ducts and the seminal vesicle exhibit peristaltic movements.

The accessory sexual organs of the male are used chiefly for copulation. They are situated upon the two or three posterior pairs of legs and vary greatly in the various species.

They are of two kinds, which may be called generic and specific. The generic parts, those which are present in all species without much modification, are a peg or blunt spine on the anterior surface of the distal end of the basipod of the posterior legs, and a semen capsule on the posterior surface of the legs next in front. The peg and the capsule face each other and are evidently supplementary in function.

So far as can be determined from preserved specimens, there are two general types of peg in the American species.

In one, represented by *funduli*, *megalops*, *alosa*, etc., the protuberance takes the shape of a spherical ball arising at the base of the exopod, but no tubercles can be seen on its surface corresponding to those found in *foliaceus* (Claus).

The ball is somewhat flattened dorso-ventrally and is supported on a short narrowed neck. Along the anterior surface of the basipod between the ball and the body is a groove formed by the raising of the edges of the basipod joints.

The ball can be elevated or partially depressed into this groove at pleasure. The ventral edge of the groove is not even, but is raised into a small flattened plate opposite the base of the ball and into another much larger one nearer the body.

These projections and a part of the ventral surface of the basipod itself are roughened by chitinous papillary elevations of the cuticle (Plates XI, XII, and XIV).

The other type of peg is present in *versicolor*, *lepidostei*, *americanus*, etc., and more closely resembles that described for *foliaceus*. It consists of a blunt papilla at the base of the exopod, very similar in form to that pictured by Claus for *foliaceus* and also covered with rough tubercles.

But from the center of the papilla there arises a long curved spine conical in shape and slightly enlarged at the very tip.

Its diameter is not more than a third that of the basal papilla, so that its point is quite sharp despite the fact that it is enlarged a trifle. On the ventral surface of the basipod are projections similar to those connected with the other type of peg, and a large triangular plate extending across the surface, both projections and plate being covered with rough chitin tubercles. The tissues around this kind of a peg are more transparent than in the other species and through them can be seen a muscle running from the very tip of the basal papilla diagonally backward to the posterior surface of the basipod, where it is attached to a small chitin thickening of the cuticle just at the tip of the triangular plate. This is the muscle which gives motion to the peg, and by it the narrow terminal part can be at least partially withdrawn into the wider basal portion. Alongside the muscle can be seen a good-sized nerve fiber which extends into the basal portion of the peg and indicates that the latter possesses a good sense of touch.

The same muscle and nerve exist in the previous type, but can not be seen as readily through the more opaque tissues (Plates XV, XX, and XXI). The semen capsule is quite a deep, pocket-shaped cavity on the posterior border of the third pair of legs opposite the peg. While the peg is confined exclusively to the distal basipod joint, both segments of the basipod share in the formation of the capsule, according to Claus.

In most species the bulk of the capsule is on the distal joint, but in at least two species, *funduli* and *megalops*, it is almost wholly on the basal joint. The lumen of the capsule is closed by flaps projecting over it from the surrounding tissues. These flaps are held open by the peg on the posterior legs while the capsule is being filled with sperm.

In addition to this peg and capsule there are various specific modifications of the three posterior legs.

These take the form of processes of various shapes attached to the anterior, the posterior, or to both surfaces of the basipods. In *megalops* the basal joint of the third legs is well rounded posteriorly and has a large thumb-shaped projection at its distal anterior corner, giving it much the appearance of a hand denuded of its fingers (Plate XI).

In *laticauda* the basipods of the third legs project posteriorly in two long flaps on each joint, the outer one narrow and finger-like, the inner one broad and well rounded (Plate X).

There are two exactly similar but rather larger projections on the posterior border of the basal joint of the second legs.

In *versicolor* there is a small finger projection from the outer end of the basal joint of the third legs on their posterior surface and a very large conical one in a similar position on the second legs. The distal basipod joint of the third legs also has a rounded knob on its anterior surface (Plate XX).



In *lepidostei* the basal joint of the second legs projects posteriorly as an enormous flap, and there is a rounded knob on the anterior surface of the distal basipod joint of the third legs similar to that in *versicolor* (Plate XVI).

In *maculosus* there is a more plentiful supply of projections and knobs; projections posteriorly at the outer ends of the basipods of the third legs and of the basal joint of the second legs, and an anterior projection at the outer end of the basal joint of the third legs; knobs on the posterior surface of the distal basipod joint of the fourth legs, on the anterior surfaces of both joints of the third legs and the same surface of the basal joint of the second legs (Plate XIX).

But it is in *americanus* that the projections reach the maximum for any species so far examined. Here at the outer end of the basal joint of the third legs on its anterior surface arises a long club-shaped projection which reaches past the distal basipod joint and extends far out on the exopod.

There is another conical projection, only slightly smaller, exactly opposite on the posterior surface of the preceding pair of legs. Both projections are profusely covered with setæ. There are also smaller projections on the opposite surfaces of the same joints as bear the large ones (Plate XXI).

#### SYSTEMATIC.

The Argulidæ were classed by Kröyer with the Siphonostoma, but Zenker in 1854 withdrew them from this group in consequence of a mistaken interpretation of the mouth parts.

Later Thorell placed the Argulidæ as a third suborder of the Branchiopoda, of equal value with the Phyllopods and Cladocera, giving as his particular reasons the unfaçetted cornea of the compound eyes, the absence of palps or branchial appendages on the oral organs, the absence of external egg sacs and spermatophores, and the fundamental form of their extremities.

But Claus in 1875 showed very clearly that the Argulidæ are much more closely related to the Eucepepoda than to the Branchiopods, and while retaining the name Branchiura given them by Thorell, he places them under the Copepoda as a second suborder of equal value with the Eucepepods.

That Claus is right and that the Argulidæ are much more closely related to the Eucepepods than to the Phyllopods has been clearly shown in the preceding ontogeny and morphology in the following points:

1. They have a flattened body which shows exactly the same general form as in the less degenerate Siphonostoma (*Caligidæ*, etc.), the same division into regions, and the same segmentation, part for part. The head is fused with the first thoracic segment, while the other thoracic

segments are free, and the abdomen is unsegmented. On the contrary, the only Phyllopod having a head shield is *Apus*, and even here the first thoracic segment is not fused with the head. The Phyllopod thorax contains many segments and the abdomen is also segmented.

2. They have the same number and grouping of the appendages as would naturally follow from the similarity in segmentation, and this grouping is entirely different from that in the Phyllopods.

3. They have two pairs of antennæ, one of which has been modified into fixing organs.

4. They have two pairs of maxillipeds, which in the larval state are quite like those of the *Siphonostoma* in form and function and are presumably of the same origin. That the anterior pair is afterwards modified into sucking disks in no way affects their relationship. It is what might be expected as a result of their parasitic habits. There are no such posterior maxillary appendages in any of the Phyllopods.

5. The mouth apparatus consists in part of a proboscis formed from the lips and jaws in a very similar way to that of the *Siphonostoma* and bearing no resemblance to that of the Phyllopods. The other part, the sting with its poison glands, is a distinctive organ, found in no other Crustacean group, and therefore to be left out of account as of no value in showing relationship.

6. The ovary is unpaired even from its beginning and though the oviduct is at first paired, one side is afterwards atrophied. The females also possess semen receptacles which differ somewhat in size and arrangement from those of the *Eucepepods*, as would be expected. But their general position, structure, and mode of operation is the same. In Phyllopods the ovaries are nearly always paired, at least in the larval period, and the semen receptacles, when present, are entirely different in position and mode of operation.

7. The swimming legs are elongated, two-branched appendages with distinctly segmented basipods, and long endopods and exopods, furnished with plumose setæ. On the two anterior legs about half the species have a flagellum attached to the basipod and pointing inward dorsally. There is nothing here which corresponds even in the remotest degree to the characteristic Phyllopod foot with its unjointed stem, its six inner lobes or appendages (endites), and its outer flat respiratory plate and sac-like branchial appendage. The *Argulidæ* breathe by means of their flattened carapace and abdomen, the Phyllopods by means of their gill-feet.

Such resemblances are conclusive, and in view of the further fact that the only particulars in which the *Argulidæ* differ at all essentially from the *Eucepepods* are such as would naturally be expected in two parasites, even if they were closely related, we may confidently adopt *Claus's* classification as correct.

Order COPEPODA Müller.

Of small size, with an elongated body distinctly segmented, except in degenerate parasitic forms. Head carapace often fused with the first thoracic segment. Four or five pairs of biramous rowing legs on the thorax and an abdomen without appendages.

(κῶπιη, = an oar, πούς, = foot.)

Suborder BRANCHIURA Thorell.

A flattened body, consisting of a shield-shaped cephalothorax in which the first thoracic segment is fused with the head, a free thorax of three segments, and a two-lobed abdomen without segments. Four pairs of swimming feet, long and furnished with two rows of plumose setæ. Two large compound eyes, movable and surrounded by a blood sinus. Testes in the abdomen. Heart present. Females without ovisacs; eggs attached to foreign objects.

(βράγχια = gills, ὄυρα = tail.)

Family ARGULIDÆ Müller.

The single family so far known of course possesses the same characteristics as the suborder. (*Argulus* = a diminutive of *Argus* in allusion to the number of parts in the compound eyes.)

ARTIFICIAL KEY TO GENERA AND SPECIES.

[The relative size of the anterior maxillipeds and the abdomen are expressed in decimal fractions; the former are fractional parts of the width of the carapace, the latter of the entire length of the animal, exclusive of the abdomen.]

- I. First maxillipeds modified into sucking disks.
  - II. Two pairs of antennæ, the anterior armed with stout hooks; preoral sting present ..... *Argulus*
  - II. Only one (the posterior) pair of antennæ; no preoral sting ..... *Chonopeltis*
- I. First maxillipeds with barbed claws; no sucking disks; no preoral sting ..... *Dolops*

ARGULUS.

- A. Carapace lobes overlapping the base of the tail.
- B. Anterior swimming legs with a flagellum.
  - C. Carapace orbicular, wider than long.
    - D. Teeth of basal plate wide and blunt, swimming legs reaching considerably beyond the edge of the carapace.
      - 1. Diameter of sucking disks, 0.25; spines on antennæ reduced in number, small and weak; abdomen relatively very small and orbicular.... *catostomi*, p. 709
      - 2. Diameter of sucking disks, 0.15; spines on antennæ large and strong, reinforced; abdomen very large and broadly cordate ..... *americanus*, p. 718
    - D. Teeth of basal plate narrow and sharp; swimming legs not reaching the edge of the carapace.
      - 3. Abdomen very small, 0.1, orbicular, with wide blunt lobes; sucking disks 0.2 to 0.25 ..... *nattereri*, female, p. 720

4. Abdomen medium, about 0.25, wider than long; lobes on basal joints of posterior legs oval, and *half the length of the legs* ..... *indicus*, p. 727
5. Diameter of sucking disks, 0.1 to 0.12; abdomen large, 0.33, elongated, with lanceolate-acuminate lobes ..... *coregoni*, male, p. 724
- C'. Carapace elliptical, considerably longer than wide.
6. Sucking disks, 0.25, situated very far forward; abdomen narrow, ovate, cut far beyond the center; color a uniform black, lighter on the ventral surface. *niger*, female, p. 714
7. Sucking disks, 0.2, not far forward, but nearer the center of the carapace; abdomen wide, elliptical, cut barely to the center; color greenish yellow. *pugettensis*, p. 711
- B'. Swimming legs without flagella.
8. Carapace covering the whole of the abdomen; last thoracic segment with lobes overlapping the abdomen (*giganteus* of Lucas) ..... *purpureus*, p. 723
- A'. Carapace lobes just reaching the base of the abdomen.
- B. Anterior swimming legs with flagella.
- C. Carapace orbicular, wider than long.
- D. Abdomen broadly triangular; anal sinus not reaching halfway to the center; legs extending beyond the carapace.
9. Anal sinus narrow and slit like; anal papillæ subterminal; bases of antennæ close to mid line of carapace ..... *versicolor*, male, p. 716
10. Anal sinus broad triangular; anal papillæ lateral; bases of antennæ widely separated ..... *maculosus*, p. 715
- D'. Abdomen long elliptical; anal sinus cut fully to the center; lobes acuminate; legs entirely covered by carapace.
11. Anal sinus narrow; papillæ basal ..... *coregoni*, male, p. 724
- C'. Carapace elliptical, considerably longer than wide; abdomen broadly elliptical; abdominal sinus short, well rounded.
12. Sucking disks about 0.25; legs not nearly reaching the edge of the carapace. *salmi*, male, p. 720
13. Sucking disks less than 0.25; legs reaching beyond the carapace. *laticauda*, male, p. 705
- A". Carapace lobes not reaching the abdomen.
- B. Anterior swimming legs with full-sized flagella.
- C. Carapace orbicular, wider than long, covering three pairs of legs, almost reaching the abdomen.
14. Abdomen large, elliptical, cut beyond the center, with acute lobes; legs reaching beyond the edge of the carapace ..... *coregoni*, female, p. 724
15. Abdomen very small, orbicular; anal sinus short, lobes well-rounded; legs not reaching the edge of the carapace ..... *salmi*, female, p. 720
16. Abdomen medium, oval; anal sinus short, slit like, papillæ subterminal; color variegated ..... *versicolor*, female, p. 716
17. Abdomen small, elliptical, not cut to the center, with rounded lobes; lobes on posterior legs large, hatchet-shaped ..... *africanus*, p. 727
18. Abdomen large, 0.63, cut beyond the center; papillæ lateral, about one-quarter the distance from the base of the sinus; longitudinal ribs forked at the anterior end ..... *phoxini*, p. 728
- C'. Carapace elliptical, considerably longer than wide.
- D. Abdomen broadly elliptical, not cut a third of its length, lobes broadly rounded; sucking disks less than 0.12.
19. Carapace lobes short and entirely free from the thorax, with spaces between; teeth on basal plate narrow and sharp ..... *chromidis*, female, p. 721
20. Carapace lobes long and overlapping the thorax; teeth on basal plate wide and squarely truncated; posterior maxillipeds large, well-armed. *laticauda*, female, p. 705

21. Carapace abruptly rounded posteriorly, narrowed anteriorly; teeth on basal plate long and sharp; anal sinus wide and shallow ..... *japonicus*, p. 727  
 D'. Abdomen cut to or beyond its center with acute lobes; sucking disks 0.2 to 0.25.
22. Carapace lobes very short, barely covering two pairs of legs; abdomen broad triangular; anal sinus also broad triangular; papillæ lateral near the tips. *lepidostei*, p. 712
23. Carapace lobes covering three pairs of legs; abdomen narrow elliptical; anal sinus narrow; papillæ basal..... *foliaceus*, p. 722
- B'. Flagella on second swimming legs rudimentary.
24. Lateral sinuses in the carapace very deep; legs completely covered. *scutiformis*, p. 728
- B''. No flagella on the swimming legs.
- C. Carapace orbicular, wider than long; sucking disks enormous, 0.33; second maxillipeds small and weak.
25. Basal plate with 3 stout teeth; legs very long; lobes on posterior legs large, boot shaped; color light yellowish white..... *funduli*, p. 710
26. Basal plate prolonged posteriorly as an entire lobe without teeth; lobes on posterior legs small; color a light brown ..... *latus*, p. 704
- C'. Carapace elliptical, longer than wide.
- D. Abdomen medium, 0.23, as broad as long, cut less than one-third; lobes broad and well rounded.
27. Antero-lateral sinuses narrow and small; cephalic area not projecting beyond the outline of the rest of the carapace; carapace not covering the bases of the third pair of legs..... *megalops*, p. 706
28. Cephalic area projecting considerably beyond the carapace outline, with a rounded protuberance on either side, medium sized in the female and in front of the sinus, very large in the male and posterior to the sinus. Carapace covering the third legs entirely ..... *dactylopteri*, p. 726
- D'. Abdomen elongate, 0.3 to 0.45, cut to the center or beyond, lobes lanceolate-acuminate.
29. Three short teeth on the basal plate; no lobes on posterior legs; sucking disks well forward; lateral sinuses of carapace shallow ..... *aloue*, p. 707
30. Only 2 teeth on the basal plate; very long acuminate lobes on posterior legs; sucking disks very far back; lateral sinuses deep..... *melita*, p. 725
31. Lateral rings of carapace fused into a single club-shaped one; teeth on basal plate particularly long and sharp..... *stizostethii*, p. 713
- A'''. Carapace very short, without posterior sinus or lobes, covering neither thorax, abdomen, nor feet.
32. Abdomen cut to the base, with lanceolate lobes; basal plate of second maxillipeds without teeth ..... *elongatus*, p. 722

## CHOXOPELTIS.

33. Carapace covering only first and second swimming legs; rudimentary flagella on first legs only; no teeth on basal plate of second maxillipeds.

*inermis*, p. 729

## DOLOPS.

- A. Carapace lobes reaching posteriorly beyond the base of the abdomen.
- B. Carapace suborbicular, wider than long.
34. Carapace entirely covering the feet; abdomen obovate, cut about one-third; anal sinus slit-like ..... *discoidalis*, p. 739
- B'. Carapace obovate, longer than wide.
35. Carapace entirely covering the feet; abdomen small and narrow, about 0.25, diamond-shaped; color grayish white, marbled with black dorsally.

*kollari*, p. 732

36. Carapace entirely covering the feet; abdomen larger, 0.33; broadly orbicular; color green, marbled with blue.....*striata*, p. 735
37. Carapace narrowed anteriorly, not covering the feet; abdomen still larger, 0.4, broadly triangular; color a uniform dark green.....*reperta*, p. 734
- A'. Carapace lobes just reaching the base of the abdomen.
- B. Carapace elliptical, longer than wide.
- C. No spines on the ventral surface; swimming feet reaching well beyond the edge of the carapace.
38. Carapace wider anteriorly; abdomen 0.5; anal sinus narrow, diamond-shaped, with the papille in the angles of the diamond; testes three-lobed.  
*raurum*, p. 737
39. Carapace wider a little behind the center; abdomen 0.65; anal sinus triangular; lobes widely divergent, acuminate; papille basal; testes two-lobed.  
*geayi*, p. 736
- A''. Carapace lobes not reaching the abdomen.
- B. Carapace orbicular, wider than long.
- C. Abdomen cut almost to the base; no spines on the ventral surface of the carapace.
40. Abdomen medium, 0.33; lobes widely divergent and acute.....*doradis*, p. 733
41. Abdomen very long, 1-5 to 2; lobes nearly parallel and acuminate.  
*longicauda*, p. 732
- C'. Abdomen cut less than one-half; ventral surface well armed with spines.
42. Abdomen short, 0.27, orbicular; basal plate of maxillipeds with only two teeth.....*bidentata*, p. 736

No figure of *Argulus africanus*, *indicus*, *japonicus*, or *scutiformis*, or *Chonopeltis inermis*, has ever been published.

#### ARGULUS Müller.

The genus possesses the same characteristics as the family and is distinguished from other genera by the presence of a sheathed stylet or sting in front of the mouth, used for a piercing organ. The anterior maxillipeds are transformed into sucking disks, while the posterior ones are armed with setæ, spines, and a chitinous plate upon their basal joint.

This plate is elevated above the surrounding surface and roughened by spines or warts, and is prolonged into three sharp spines on its posterior border. There are two pairs of antennæ, the anterior of which are armed with stout sickle-shaped hooks and function as organs of prehension. The basal joints of the posterior swimming legs are usually prolonged into lobes projecting beneath the abdomen.

#### ARGULUS LATUS Smith.

##### Plate IX.

*Argulus latus* SMITH, Invertebrate Animals of Vineyard Sound, Report of U. S. Com. Fish and Fisheries, 1872.—RATHBUN, Annotated List of Parasitic Copepoda, Proc. U. S. National Museum, VII, 1884.

Carapace orbicular, wider than long; posterior sinus about one-fifth the length of the carapace, as wide as long; abdomen a third as long as the carapace, two-thirds as broad as long, the lateral margins slightly curved and nearly parallel; anal sinus very broad, about one-third the

whole length; anal papillæ basal. Disks of the anterior maxillipeds nearly one-third the width of the carapace; plate at base of posterior maxillipeds prolonged backward as a whole, without teeth or lobes; ultimate segment longer than the penultimate, hooks short and blunt.

First antennæ very short, without any hook on their anterior margin; second antennæ also short; swimming legs all reaching beyond the edge of the carapace. No flagella. Color yellowish-white.

Length, 2.3 mm.; length of carapace, 2.2 mm.; width of carapace, 2.5 mm.; length of abdomen, 0.7 mm.; breadth of abdomen, 0.45 mm. Male unknown.

6181. Vineyard Sound, Massachusetts; U. S. Fish Com., July, 1871; one female, the type, taken at the surface. ————. Casco Bay, Maine; U. S. Fish Com., 1873; one female, no data. 6184. Quahaug Bay, Maine; host not given.

(*latus* = wide.)

#### ARGULUS LATICAUDA Smith.

Plate X; Plate XXVI, fig. 79.

*Argulus laticauda* SMITH, Invertebrate Animals of Vineyard Sound, Report of U. S. Com. Fish and Fisheries, 1872.—RATHBUN, Annotated List of Parasitic Copepods, Proc. U. S. National Museum, VII, 1884.

Carapace elliptical, longer than wide; posterior sinus about one-third the length of the carapace, twice as deep as wide.

Abdomen orbicular, slightly longer than broad; anal sinus narrow, extending scarcely a fourth the length; anal papillæ basal.

Disks of anterior maxillipeds small, about one-eighth the width of the carapace, placed well back; basal plate on posterior maxillipeds narrow, but expanding into a wide posterior margin, cut into three broad, squarely truncated lobes. A papillated area near the center of the plate; a row of spines along the posterior margin of the three basal joints. Spines on the bases of the antennæ large, broad, and blunt. Males much larger comparatively than in other species, the basal joints of their three posterior pairs of legs prolonged backward into fleshy lobes, the outer ones narrow and finger-like, the inner ones occupying the remainder of the joint. Flagella present.

Length of male 5 to 6 mm.; length of carapace 3.5 to 4 mm.; width of carapace 3.2 to 3.5 mm.; length of abdomen 1.3 mm., breadth 1.1 mm.

Smith's types were two females taken from among algae in Vineyard Sound, Massachusetts, in August, 1871 (Museum number, 6182).

Since then they have been obtained in large numbers from various fishes, those in the National Museum collection being numbered as follows: From the Eel (*Anguilla chryssypa* Rafinesque), Nos. 1311, 1318, and 1398, collected by V. N. Edwards; 6013<sup>1</sup>, 6013<sup>2</sup>, 6177, 8278, 8279, 12294; a lot from Katama Bay by Thompson. From Flatfish (*Pseudopleuronectes americanus* Walbaum), Nos. 1433, V. N. Edwards; 6152, 6171; a lot from Katama Bay by Thompson, another from Woods Hole

by H. M. Smith. From Blenny (sp.), No. 6054. From Skate (sp.), No. 12302. From Sculpin (sp.), No. 12291. From "Bonnet Skate," one lot by Thompson. From Tomcod (*Microgadus tomcod* Walbaum), No. 15446. From Summer Flounder (*Paralichthys dentatus* L.), one lot by Thompson.

Color a mottled black, except at the very edge of the carapace, back of the eyes, and around the brain, where it is yellowish; the mottlings vary much in different individuals in size and extent, and are sometimes reddish brown.

This still continues, as Rathbun stated in 1884, the most abundant of the genus among the salt-water forms, though *megalops* is found on a greater variety of hosts.

(*latus*=wide, *cauda*=tail).

#### ARGULUS MEGALOPS Smith.

Plate XI; Plate XXVI, fig. 81.

*Argulus megalops* SMITH, Invertebrate Animals of Vineyard Sound, Report of U. S. Com. Fish and Fisheries, 1872.—RATHBUN, Annotated List of Parasitic Copepods, Proc. U. S. National Museum, VII, 1884.

Carapace elliptical, longer than broad; antero-lateral sinus narrow and deep, posterior sinus narrow triangular and shallow; abdomen broad elliptical, two-thirds as broad as long; anal sinus narrow and short; papillæ basal. Sucking disks medium size, situated well forward; basal plates on posterior maxillipeds, as well as the maxillipeds themselves, large and fully armed. The median spines between these posterior maxillipeds are slender and strongly curved. Antennæ rather slender, armed with narrow, sharp spines and hooks. Eyes quite large, their diameter about one-tenth that of the carapace.

Swimming legs long, projecting some distance beyond the carapace; lobes on the basal joints of the posterior legs in the female with a narrow, conical projection pointing outward. No flagella.

The peg on the posterior legs of the male takes the shape of a flattened spherical ball with a short, narrowed neck.

On the side of the peg next the body there is a groove in the anterior surface of the basipod into which the ball can be partially depressed. On the basal joint of the third legs is a stout thumb-shaped projection extending forward from the distal end of the joint. Smith's three type specimens were females taken at the surface in Vineyard Sound, Massachusetts, July 8, 1871. They were evidently young females, since those since obtained are much larger, as will be seen from the measurements here given. This species has a larger number of hosts than any other thus far found, the most common one being the Flatfish (*Pseudopleuronectes americanus* Walbaum). The Museum numbers for this fish are 1322, 1460, and three unnumbered lots from Woods Hole by V. N. Edwards; 8276, 8238 (in part), 12032, 12295, 12296; two unnumbered lots by Thompson, one from Woods Hole and the other



from Menimsha; an unnumbered lot off Cape Cod. From Sand Dab (*Hippoglossoides platessooides* Fabricius), Nos. 1407 by V. N. Edwards; an unnumbered lot by Thompson from Woods Hole. From Summer Flounder (*Pardalichthys dentatus* Linnaeus), Nos. 6067, 8638. From Spotted Flounder (*Lophopsetta maculata* Mitchill), No. 6069. From Sea Robin (*Prionotus carolinus* Linnaeus), Nos. 8275, 8639; one unnumbered lot by Thompson. From Sculpin (*Myoxocephalus octodecimspinosus* Mitchill), Nos. 8281, 12290. From Tomcod (*Microgadus tomcod* Walbaum), No. 8280. From Goosefish (*Lophius piscatorius* Linnaeus), No. —, Woods Hole. From Minnow (sp.), No. 6105. From Flounder (sp.), No. 12297. From surface tow, No. 6179 (types); one lot unnumbered, Woods Hole. No host given, two lots, August 13 and November 21, 1885, by V. N. Edwards.

On examining this list and the one previously given for *A. laticauda* it will be seen that both species infest fishes which live on or very near the bottom. With the exception of those taken in the surface tow, whose presence has already been explained (p. 645), there is no deviation from this rule.

Hence, although the Arguli may and do change about quite freely from fish to fish, especially during the breeding seasons, it would seem as though they did not vary their level very much.

And in a plankton distribution we might reasonably expect to find at least these two species pretty definitely located. The hosts of some of the other species do not stay quite so closely at the same level, and hence the range of the parasite would be enlarged by that of its host.

Length, 6 mm.; length of carapace, 3.8 mm.; width of carapace, 3.5 mm.; length of abdomen, 2 mm.; breadth, 1.4 mm.

Color in fresh specimens yellowish, with four delicate pale brown longitudinal bands. The entire upper surface of the abdomen in ripe females is a red brown inclining to pink, thickly sprinkled with minute black dots. The lateral flaps of the carapace are also ornamented with an arborescent design in black pigment, similar to that shown in the photograph of *aloseæ* (fig. 80). After death the females frequently become a uniform bright pink.

(μέγας = large, ὄφ = eye.)

#### ARGULUS ALOSÆ Gould.

Plate XII; Plate XXVI, fig. 80.

*Argulus alosæ* GOULD, Invertebrata of Massachusetts, 1841.—THORELL, Om tvenna Europeiske Argulider, etc., Öfvers. af Kongl. Vetensk.-Akad. Förhandlingar, 21st series, Stockholm, 1864.—SMITH, Invertebrate Animals of Vineyard Sound, Report of U. S. Com. Fish and Fisheries, 1872.—RATHBUN, Annotated List of Parasitic Copepods, Proc. U. S. National Museum, VII, 1884.

Carapace elliptical, longer than wide; antero-lateral sinus shallow but often becoming deep and sharp on shrinking in alcohol, so that the cephalic area protrudes in a sort of semicircle.

Posterior sinus rather narrow, about one-third the length of the carapace, three times as long as wide; lobes well rounded.

Sucking disks large, about one-fifth the width of the carapace; posterior maxillipeds medium with a triangular basal plate armed with three short blunt teeth, and strongly papillated.

Antennae small and armed with rather weak spines and hooks. The body projects considerably beyond the carapace, the thoracic segments being long and wide; the posterior one projects over the abdomen as a well-rounded lobe on either side with a shallow sinus between. Abdomen broad and long, more than one-third the length of the rest of the body, with well-rounded lateral margins. Anal sinus broad triangular, cut to the center, leaving the two lobes sharply pointed and flaring slightly at their tips; papillae small and basal. Swimming legs long, projecting far beyond the carapace; lobes on the basal joints of the posterior pair small and rectangular. Abdomen in the male very much longer, but no modifications of the legs except the regular peg and semen vesicle. No flagella.

Length, 7.8 mm.; length of carapace, 4.8 mm.; breadth of carapace, 3.8 mm.; length of abdomen, 2.2 mm.; breadth, 1.7 mm.

Color, a yellowish white, mottled along the carapace lobes with brown. Some specimens measure 12 by 6 mm. (See photograph, fig. 80.)

This species was discovered by Dr. T. W. Harris in 1841 upon the gills of the alewife (*Clupea vernalis* Mitchell).<sup>1</sup>

The single specimen was sent to Dr. A. A. Gould for determination and description; he published a very short and meager description accompanied by a coarse woodcut, from neither of which could any specific characters be determined. The species has rested upon this unsatisfactory basis ever since and has of necessity been more or less doubtful. It is hoped that the present description and figures will establish it satisfactorily. It occurs in considerable abundance along the Atlantic coast, but has never yet been found on any species of shad, which makes its name rather inappropriate.

The Museum collection includes: From the alewife (*Pomolobus pseudoharengus* Wilson), Nos. 1310 (by V. N. Edwards), 12680, 11619. From the smelt (sp.), an unnumbered lot, Woods Hole. From unknown hosts, Nos. 4410 from Great Egg Harbor; 7739 from Key West, and two unnumbered lots, one from Woods Hole and the other from Patchogue, Long Island. This Argulus has also been doubtfully recorded by Mr. J. F. Whiteaves as attached to *Gasterosteus biculeatus* Shaw, in the Gulf of St. Lawrence.

(*alose* = from *alosa*, the supposed generic name of its host; *clupeae* would be far more appropriate).

<sup>1</sup> Gould identifies this fish as the European *Alosa vulgaris*, but this form does not occur on our coasts, while the alewife is quite common and from it have been obtained most of the recent specimens.

## ARGULUS CATOSTOMI Dana and Herrick.

## Plate XIII.

*Argulus catostomi* DANA and HERRICK, Description of the *Argulus catostomi*, Amer. Jour. Sci., XXXI, 1837.—MILNE-EDWARDS, Hist. Nat. des Crustacés, III, 1840.—THORELL, Om tvänna Europeiske Argulider, etc., Öfvers. af Kongl. Vetensk.-Akad. Forhandlingar, 21st series, Stockholm, 1864.

Carapace orbicular, wider than long; posterior sinus nearly one-third the length of the carapace, broad with parallel sides. Abdomen orbicular, wider than long, but relatively very small, not more than one-fourth the length of the carapace; anal sinus narrow, almost slit-like, scarcely one-third the whole length of the abdomen; papillæ basal.

Disks of the anterior maxillipeds large, nearly one-fourth the width of the carapace broad as the latter is; posterior maxillipeds also large, every joint with a roughened area on its ventral surface; basal plate broad triangular, with wide lobes on its posterior edge instead of teeth, sometimes two and sometimes three. Antennæ small and weak, the anterior pair without a hook on their front margin, while the spines on the bases of both pairs are reduced to two insignificant pimples.

The anterior swimming legs scarcely reach the edge of the carapace; lobes on the posterior pair large, boot-shaped.

A large papilla present on either side of the opening of the oviduct. The arrangement of the chitin rings in this species is characteristic; the larger one extends along the edge of the carapace lobe as far forward as the sucking disks; at about the center of its inner surface is a deep indentation into which the smaller ring fits snugly, the latter being situated in the clear space just behind the posterior maxillipeds. Flagella present. Eyes quite small.

Length, 12 mm; length of carapace, 9.6 mm; breadth of carapace, 11.2 mm; length of abdomen, 2.3 mm; breadth, 2.4 mm.

Color a light sea-green, inclined to yellowish, growing quite dark in alcohol.

This was the first American species to be described, and with the possible exception of *funduli* and *pugettensis* it is the only one that has ever been given anything like a decent figure. For this reason it has been willingly accepted by the European zoologists, and has taken the same place in American parasitic copepods that *A. foliaceus* occupies in the European fauna.

It was first discovered on a sucker (probably *Catostomus bostonensis* Le Sueur) in brackish water near New Haven, Connecticut.

It has recently been found abundantly by the author upon the same sucker in fresh water at Warren and Chicopee, Massachusetts.

But it is even more abundant upon the chub sucker (*Erimyzon succetta oblongus* Mitchell), which is nearly always found with the other

species in these inland waters. It stays within the gill cavity, and has never yet been found upon the external surface, but there is every reason to believe that at least the males come out upon the external surface during the spawning season. The National Museum collection contains specimens from both the above localities and also a single specimen, a female, taken from carp at Fairburg, Illinois. None of these lots are numbered. In all probability future investigation will discover this species wherever the sucker is found in the United States.

(*catostomus* = generic name of its most common host, the sucker.)

#### ARGULUS FUNDULI Kröyer.

Plate XIV.

*Argulus funduli* KRÖYER, Naturhist. Tidsk. 3die Raekke, 2 Bind, 1863.—THORELL, Om tvenna Europeiske Argulider, etc., Öfvers. af Kongl. Vetensk.-Akad. Forhandlingar, 21st series, Stockholm, 1864.

Carapace orbicular, broader than long; posterior sinus less than one-fifth the length of the carapace, wider than deep, in the female nearly as two to one. Abdomen in the male fully one-half the length of the rest of the body, nearly three times as long as wide, with a narrow anal sinus less than a fourth of its length. Abdomen in the female much smaller, less than a third the length of the carapace, three-fifths as wide as long, with a wide anal sinus half its length; papillæ basal.

The sucking disks are relatively the largest of any American species, being almost one-third the width of the carapace; posterior maxillipeds correspondingly small and weak; teeth on the basal plates short and blunt. Antennæ of moderate size and fairly well armed. The whole ventral surface of the thorax roughened in the female. Swimming legs long, reaching well beyond the edge of the carapace; basal joints of the posterior legs in the female with medium-sized, rather rectangular lobes; these lobes much diminished in size in the male, and conical.

Eyes very large, fully the size, relatively, of those in *megalops*.

Pigment on the upper surface of the ovary and testes rather more plentiful than in most species. No flagella.

Length of female 5 mm., of male 3.3 mm.; length of carapace, female 3.1 mm., male 1.8 mm.; breadth of carapace, female 3.5 mm., male 2 mm.; length of abdomen, female 1.1 mm., male 1.2 mm.; width, female 0.6 mm., male 0.4 mm.

Color of alcoholic specimens uniform yellowish-white.

This *Argulus* was obtained from the gills of a species of *Fundulus* near New Orleans in 1862. Kröyer gave the fish the manuscript name *Fundulus limbatas*, which has been changed by Jordan and Gilbert to *F. ocellaris*. But both Kröyer and Thorell made a serious mistake in

reference to the parasite, the latter simply repeating the mistake of the former.

Krøyer describes and portrays what he calls a female of the species, which was the only specimen obtained. His figure shows at once that he has mistaken the sex and has really a male.

The length of the abdomen, the size of the testes, and the accessory copulatory organs on the posterior legs are unmistakable proofs of this. Thorell also states that both the male and female are known, which would manifestly be rather difficult from a single specimen. So far as known the present description and figure of the female are the first published.

That this is really the female of the species was very pleasantly confirmed after the description had been written by finding a male and female in the material sent for examination from the Ohio State University, which had been taken together from the same "minnow." The habitat of this species must now be extended to include the whole Atlantic coast, for the National Museum collection includes No. 6153, taken from among many fish at Waquoit, Connecticut; No. 6180, from Long Island Sound, and an unnumbered specimen from Woods Hole. (*fundulus*=generic name of its host.)

#### ARGULUS PUGETTENSIS Dana.

##### Plate XV.

*Argulus pugettensis* DANA, U. S. Exploring Expedition during the years 1838-1842, under the command of Charles Wilkes, U. S. Navy, XIII, Crustacea.—THORELL, Om tvenna Europeiska Argulider, etc., Öfvers. af Kongl. Vetensk.-Akad. Forhandlingar, 21st series, Stockholm, 1864.

Carapace elliptical, longer than wide, entirely covering the legs; posterior sinus rather narrow, two-fifths the length of the carapace. Abdomen large, broad elliptical, nearly half the length of the rest of the body; anal sinus broad triangular, cut fully to the center, lobes subacute; papillæ basal.

Sucking disks a little more than a quarter the width of the carapace and close together; posterior maxillipeds large and well armed; basal plate broadly wedge-shaped, teeth short, blunt, and far apart. Antennæ medium size, but very poorly armed. Swimming legs short, just reaching the edge of the carapace, furnished with flagella; lobes on the posterior pair small and scarcely projecting. Oviduct papillæ small.

Color, yellowish white in alcoholic specimens.

Length, 17.3 mm.; length of carapace, 12.8 mm.; width of carapace, 10 mm.; breadth of abdomen, 4 mm.; length, 5.3 mm. Male unknown.

*Habitat*.—From the shores of Puget Sound. Host unknown. (*Pugettensis*=from the name of its habitat.)

## ARGULUS LEPIDOSTEI Kellicott.

Plate XVI.

*Argulus lepidostei* KELLICOTT, description of a new species of Argulus, Bull. Buffalo Soc. Nat. Sci., III, 1877.

Carapace elliptical, longer than wide; posterior sinus less than one-third the length of the carapace, wider than deep.

Abdomen broad ovate, more than one-third the length of the rest of the body, as wide as long; anal sinus broad triangular, cut half the length of the abdomen; papillæ lateral, near the tips of the acute lobes. Sucking disks medium size and placed well forward; posterior maxillipeds rather small but stout and well armed on their ventral surface, their basal joint wider than that of the swimming legs; basal plate narrow, abruptly triangular posteriorly; teeth long, narrow, and very sharp.

First antennæ rather weak, having two slender hooks, but only a single very small spine; second antennæ larger and better armed. Swimming legs reaching beyond the edge of the carapace; lobes on the basal joints of the posterior legs enormous, boot-shaped, reaching beyond the edge of the abdomen.

Flagella present; a long slender papilla on either side of the opening of the oviduct. In the male the abdomen is considerably lengthened, with a rounded lobe on either side at its base; in addition to the regular accessory copulatory organs, the basal joint of the second legs is prolonged backward into a wide flap, reaching beyond the third legs, and there is a rounded knob on the anterior surface of the second joint of the third legs at its distal end. Eyes very small, brownish in color.

Color a light yellowish green, with the upper part of the body blotched and streaked with violet brown.

Length, 6.2 mm.; length of carapace, 3.75 mm.; breadth of carapace, 3.5 mm.; length of abdomen, 1.75 mm.; breadth, 1.7 mm. Male about two-thirds this size.

This species was found parasitic on *Lepidosteus osseus* Linnaeus, in the Niagara River, at Buffalo, in September, 1876, by D. S. Kellicott, who described and figured the female in the periodical above referred to. He had not at that time obtained any males.

Through the kindness of Prof. Henry Osborn, of the Ohio State University, at Columbus, where Professor Kellicott was stationed for many years, I have been enabled to examine personally Kellicott's types. I find among them a male which is here described for the first time. Professor Kellicott writes that—

The favorite place for the parasite to fasten is immediately back of the pectoral fins of its host. It often left the fish and swam about the tank, then returning fastened to any part presented, and crawled to its place near the pectoral fins. I have reason to believe that it may also occupy the gill cavities.

The types of this species are in the museum of the State University at Columbus, Ohio.

(*lepidosteus*=generic name of its host.)

ARGULUS STIZOSTETHII Kellicott.

Plate XVII.

*Argulus stizostethii* KELLICOTT, Amer. Jour. Micros., V, 1880, p. 53.

Carapace elliptical, much longer than wide; posterior sinus one-third the length of the carapace, twice as long as wide.

Abdomen long and narrow with parallel sides, one-half the length of the rest of the body, twice as long as wide; anal sinus cut beyond the center, narrow and slit-like toward the base, but flaring widely toward the tip; lobes acute; papillæ basal.

Cephalic area projecting considerably anteriorly. Sucking disks large, more than one-quarter the width of the carapace; posterior maxillipeds large and stout, their ventral surface thickly covered with setæ; basal plate large, triangular, and armed with stout sharp teeth. Antennæ large and well armed, median spine at the base of the second pair particularly stout. Swimming legs reaching far beyond the edge of the carapace; lobes on the basal joints of the posterior legs small and conical. Flagella present; small papillæ at the opening of the oviduct. Chitin rings in the lateral lobes of the carapace fused into one whose anterior end is about the normal size, while the posterior part is much narrowed, giving the whole ring a club-shaped appearance.

In the male the distal joint of the basipod of the second pair of swimming legs carries upon its ventral surface a large fleshy plate or lamella which projects backward, outward, and inward beyond the respective margins of the joint, and whose surface is covered with small sharp spines. There are also the usual capsule and peg on the third and fourth legs, respectively, while the lobe on the basal joint of the posterior legs is smaller than in the female. The carapace is shorter than in the female, barely covering the second swimming legs; the abdomen is relatively much longer and narrower, and in Kellicott's figure it is represented as fringed with setæ.

Length, 6.6 mm.; length of carapace, 4.2 mm.; breadth of carapace, 3.1 mm.; length of abdomen, 2 mm.; breadth, 1.1 mm.

These are the measurements of the specimens at my disposal, but Kellicott says that the females reach a size of 0.55 inch, which would be more than twice the above measurements. The males are about three-quarters as large.

*Color*.—Males and immature females are nearly colorless, with the sexual organs brown; mature females have the carapace, legs, and abdomen pale pea-green. The upper side of the thorax is darkened by the usual pigment spots, while the under side is white from the ripening eggs. "There is a light line along the dorsum."

*Habitat.*—Found on the blue pike, *Stizostethium salmoneum* Jordan, in the Niagara River at Buffalo; named from its host.

Kellicott verifies the statement of the local fishermen that during midsummer when the water is warm this blue pike “gets too lazy to take food; that it then gets poor and, through its inertness, becomes infested with lice.” They are usually found on the top of the fish’s head, often “huddled together in heaps, so the knife may remove a number at once.” They occur also on the fins, but have never been found in the mouth cavity. Kellicott’s paper descriptive of this species could not be found till just before this article went to the printer, but the author was gratified to find in it observations confirmatory of several of the habits of Argulids recorded here:

When put into my aquarium with a small specimen of *Lepidosteus osseus* and some minnows, they shortly located on them, fastening as before to the head and fins of the gar-pike, but to any part of the minnows; these latter soon die, killed apparently by the Argulus (p. 652).

At first these fish pursued and caught them, “but would eject them with a suddenness and a queer expression of frustration that was most amusing” (p. 647).

The gar even recoiled “in evident fear from one seen approaching.” The removal of the scales from portions of the body surface in the fish that died, as noted by Kellicott, is readily explained by the fact already mentioned (p. 650) that the Argulids burrow in under the scales to find a place where the skin is soft enough for their stings to penetrate.

Through the kindness of Mr. William E. Kellicott, son of Prof. D. S. Kellicott, the author obtained a mounted specimen of this species for examination, and others were found in the material so generously sent from the Ohio State University.

From these and from Professor Kellicott’s own description, which was found at the last moment through the aid of his son, the above facts have been drawn.

The fused chitin rings and the elongated abdomen are distinguishing characteristics of this species.

#### ARGULUS NIGER, new species.

##### Plate XVIII.

Carapace elliptical, longer than wide; antero-lateral sinuses sharp, but not deep; posterior sinus narrow and half the length of the carapace. The entire body and half the abdomen covered by the carapace lobes, which overlap across the back of the thorax. Abdomen broadly ovate, one-third the length of the rest of the body, the sides strongly rounded; anal sinus narrow, cut two-thirds the length of the abdomen, lobes rounded-acute; papillae basal. Sucking disks very large and far forward, one-fourth the width of the carapace; posterior maxillipeds



not large but stout, with a swollen terminal joint furnished with a pair of forceps-like hooks; basal plate triangular, teeth broad and blunt. Median spines between these maxillipeds with papillated plates at their bases. Antennæ medium sized and well armed with wide blunt spines. Swimming legs hardly reaching the edge of the carapace; lobes on the posterior ones very small. Flagella present; papillæ at the oviduct opening reduced to mere pimples. Color of alcoholic specimens a uniform dark brownish black on the dorsal surface, lighter below, with a narrow edge of yellow around the carapace, and yellowish areas around the eyes and brain.

Both surfaces of the abdomen are brownish yellow covered with small black spots, more numerous on the dorsal than on the ventral side.

Length, 14 mm.; length of carapace, 11 mm.; breadth of carapace, 9 mm.; length of abdomen, 4 mm.; breadth, 3.25 mm.; breadth of sucking disks, 2.25 mm. Male unknown.

Two specimens, both females, were obtained by the U. S. Fish Commission steamer *Albatross* at Portland, Oregon, October 2, 1889. Name of host not given. No number.

(*niger* = black.)

#### ARGULUS MACULOSUS, new species.

Plate XIX; Plate XXVI, fig. 82.

Carapace orbicular, length about the same as the width; posterior sinus reaching one-third the length of the carapace, wide at the base but posteriorly the lobes approach until they almost touch; antero-lateral sinus well defined.

Abdomen bluntly triangular, one-third the length of the rest of the body, a trifle wider than long; anal sinus broad triangular, reaching one-quarter the length of the abdomen; papillæ lateral, near the tips of the well-rounded lobes.

Sucking disks of medium size, placed rather near together; posterior maxillipeds small; basal plate rectangular, with three sharp teeth; ventral surface not much roughened.

Antennæ large, the anterior ones without any hook on their front edge; the basal spines large, and the one on the posterior antenna reinforced by a second as large as itself. These antennæ are widely separated anteriorly and approach each other posteriorly, so that this heavy armature of basal spines makes a conspicuous V of dark-colored chitin in front of the sucking disks.

Swimming legs reaching beyond the edge of the carapace; lobes on the posterior pair large, boot-shaped, reaching beyond the edge of the abdomen. Flagella present; papillæ at the opening of the oviduct long and narrow. Male about one-quarter smaller than the female, its abdomen of approximately the same shape. Beside the

regular peg and semen vesicle this species shows a number of protuberances on the legs of the male; the basal joint of the second pair has a rounded knob on the anterior surface next the body, and on the posterior surface at the distal end another rounded knob, and outside of this a long, finger-like projection. Both basal joints of the third pair have conical projections extending diagonally outward from their distal ends, that on the first joint being anterior and on the second joint posterior. The second joint of the last pair of legs also has a rounded knob on its posterior surface, and the peg on this joint is a spherical ball.

The posterior chitin ring in the carapace lobes is very broad, and its anterior end is slightly concave and extends diagonally outward and forward from near the base of the first pair of legs. Into the concavity fits the very much smaller anterior ring, so that the two form a symmetrical outline.

Color of alcoholic specimens a yellowish white, thickly spotted with brown over the entire dorsal surface and on the ventral surface of the abdomen, whence the name *maculosus*, spotted.

Length, 9.8 mm; length of carapace, 7.8 mm.; breadth of carapace, 7.9 mm; length of abdomen, 2 mm; breadth, 2.1 mm. Male about two-thirds this size.

The National Museum collection contains two lots of this species, one consisting of 14 specimens, 11 females and 3 males, unlabeled, the other a single female taken by Fred Mather from *Esox nobilior* Thompson, at Clayton, New York, and numbered 12226. This identifies it as a fresh-water species, which is also indicated by its close resemblance in many particulars to the two following species. In all probability it can be found upon the muscalonge elsewhere.

#### ARGULUS VERSICOLOR, new species.

Plate XX; Plate XXVI, fig. 83.

Carapace orbicular, about as wide as long; posterior sinus one-third the length of the carapace, twice as long as wide.

Abdomen ovate, three-sevenths the length of the rest of the body, longer than wide; anal sinus very narrow and slit like, only reaching one-sixth the length of the abdomen; papillæ subterminal. Sucking disks medium size, very symmetrically placed far apart, near the anterior edge of the carapace; posterior maxillipeds also medium size, well armed; basal plate somewhat wedge-shaped, with long and blunt teeth.

Antennæ large, long, and armed with powerful hooks and very long sharp spines, those at the base of the second antennæ reenforced by other smaller ones. Proboscis long and wide, sting narrow and very sharp. Swimming legs reaching far beyond the edge of the carapace,

and hence very long; the lobes on the posterior pair medium size, boot-shaped, reaching just to the edge of the abdomen. Flagella present; papillæ at the oviduct opening of good size and thickset.

Larger chitin ring in the carapace lobes extending forward opposite the base of the posterior maxillipeds, concave on its inner surface at the anterior end, and into this concavity the other very much smaller ring fits. This leaves the front of the carapace clear, unlike the other species.

In the male the second legs have a large conical projection on their posterior surface at the outer end of the basal joint.

There is a similar much smaller one in a corresponding position on the third legs, and these legs also have a rounded knob on the anterior surface of the second joint at the end next the body. The regular lobes on the basal joints of the last legs are longer and more slender than in the female, and are separated from the joint itself at the heel as well as at the toe.

This is a very clean-looking Argulus, and by far the most beautiful of any American species. It is a veritable Joseph among its brethren in the colors of its coat. The chitin framework and the spines on the ventral surface are a clear orange, the longitudinal ribs of the carapace having the orange bordered by yellow-green. The digestive tube is a deep wine red anteriorly, fading into yellow-green in the abdomen.

The testes and semen receptacles are a still deeper red, almost purple. The ground color of the body is a yellow-green, this color forming a wide border around the edge of the carapace and extending inward diagonally as a wide band on either side from the edge just behind the sucking disks to the base of the posterior sinus.

From the center of these diagonal bands another narrower band of the same color extends backward parallel with the edge of the carapace to near the posterior border of the lobes. At about their center these last bands are joined with the border along the edge by radial bands. In addition to these bands there are areas of the same color just outside the sucking disks and a large one in either lobe opposite the base of the first swimming legs.

The rest of the surface is filled in with orange-yellow of various shades, the posterior part of the lobes being tinged with brown, while over the side branches of the stomach it takes more or less of a reddish hue from the stomach contents. As may well be imagined, the whole presents a beautiful variegated appearance, whence the name given to the species. But the most wonderful thing about these beautiful colors is their permanency. They are "fast" colors in the fullest sense of the word, for they defy any preservative so far tried. Chrome-acetic and corrosive-acetic, Perenyi's and platinum chloride have no effect upon them, and after preservation in these solutions they have been kept in alcohol for over a year with so little change of

color that they can hardly be distinguished from fresh specimens, save for their greater opacity.

This species was first found by the author upon some common pickereel (*Lucius reticulatus* Le Sueur) caught through the ice at Powdermill Pond, Warren, Massachusetts. They have since been found on the same fish in Wickaboag and Podunk ponds, Brookfield; in Lake Lashaway, between Brookfield and Spencer; in Ashley Ponds, Holyoke; and in Congamon Ponds, Southwick, all in Massachusetts.

In fact, they have not been looked for in a single pond where they have not been found, and in all probability they infest this fish more or less throughout its habitat.

They can be distinguished from all other species at a glance by their brilliant coloration.

Length, 6 mm.; length of carapace, 4.4 mm.; breadth of carapace, 4.9 mm.; length of abdomen, 1.6 mm.; width, 1.6 mm.

(*versicolor* = variegated.)

ARGULUS AMERICANUS, new species.

Plate XXI; Plate XXVI, figs. 84-86.

Carapace obovate, as wide as long; posterior sinus narrow, extending one-third the length of the carapace, quite square at the base, but the sides converge quickly and the carapace lobes overlap considerably at their tips. Abdomen broadly triangular, one-half wider than long; anal sinus broadly triangular; papillæ subterminal. Sucking disks small, one-sixth the width of the carapace; posterior maxillipeds also rather small, but well armed; basal plate narrow, triangular, with wide squarely truncated plates on its posterior border in place of teeth, thus resembling *versicolor* and *catostomi*.

Antennæ rather small but furnished with strong hooks and spines; two spines instead of one at the bases of the posterior pair. Swimming legs long and very slender; lobes on the posterior pair very large, boot-shaped, with a distinct heel.

In the male, beside the regular copulatory organs, there are very long projections on the basal joints of the second and third legs at the distal ends. Those on the second legs are conical and on the posterior surface, those on the third legs are flattened, club-shaped, and on the anterior surface.

There are also smaller projections on these same joints opposite the large ones, and a rounded knob on the anterior surface of the second joint of the third legs. The abdomen in the male is scarcely elongated at all.

Flagella present; papillæ at the oviduct opening long and stout. Chitin rings in the carapace lobes similar to those in the last two species, but not extending quite as far forward. To compensate for the mediocre size of the two pairs of maxillipeds, we find the ventral sur-

face of the carapace thickly covered, over its anterior half, with large, sharp spines.

These spines are found on every species in greater or less abundance, but they are especially large and prominent on *americanus*. The color is a pale brownish white, sparsely covered on the ventral and dorsal surfaces with small pigment spots of a slightly darker hue. When alive this species is particularly transparent, and shows the side ramifications of the stomach very plainly. (See photograph, fig. 84.) This is one of our most typical American fresh-water species. The American continent, with the accession of the species here added, resumes once more the old position accorded it by Kroyer and Thorell as the proper habitat of the genus *Argulus*; and, lastly, the only host upon which this particular species has thus far been found is a genus of fish exclusively American (*Amia*). These reasons have suggested the specific name *americanus* as appropriate.

Length 10 mm.; length of carapace 8 mm.; breadth of carapace 8 mm.; length of abdomen 2.5 mm.; breadth 4 mm.

This species infests *Amia calva* Linnaeus in our Great Lakes region to such an extent as to become a nuisance when the fish are kept in aquaria. About 100 specimens were sent to the author by Prof. Jacob Reighard from Ann Arbor, Michigan, who wrote that he had been obliged to have the *Amia* cleaned to rid them of these pests. He also kindly sent the excellent photographs of the animal as an opaque object which show very clearly its specific characteristics. A dozen of these animals were sent in a mailing case from Ann Arbor to Westfield, Massachusetts, and every one was alive when received and lived for about a week afterwards.

An effort will be made in the near future to obtain ripe females in this way and follow the development of the species.

This concludes the North American species so far found, just half the entire genus, while of the other half four out of the thirteen species belong in Central or South America, leaving but nine species from all other localities combined.

It is well to recall again in this connection that the present is the first attempt to collect all the American species and must therefore be incomplete. By the time anything like as much work has been done in America as in Europe we may confidently expect that the preponderance of American species will be even greater than now.

Of the thirteen North American species here presented the location of the type of *pugettensis* is unknown, if indeed it has not been lost; the types of *lepidostei* and *stizostethii* are in the museum of the Ohio State University, while the types of the other ten species are in the National Museum. Five species are described for the first time; two others are removed from the doubtful list and the missing sex supplied, while the males of five out of the remaining six species are here first

distinguished. The non-American species of the family will be treated very briefly and from a purely systematic standpoint, after first describing the four from Central and South America.

**ARGULUS NATTERERI** Kollar.

Plate XXII, fig. 63.

*Argulus nattereri* HELLER, Beiträge zur Kenntniss der Siphonostomen. Sitzungsber. d. kais. Akad. d. Wissensch., Math.-naturwissensch. Cl., XXV, 1857.—KRÖYER, Bidrag til Kundskab om Snyltekrebsene. Naturhist. Tidskr., 3die Række, 2 Bind, 1863.—THORELL, Om tvenna Europeiske Argulider, etc. Öfvers. af Kongl.-Vetensk. Akad. Forhandlingar, 21st series, Stockholm, 1864.

Carapace orbicular, wider than long; posterior sinus narrow, reaching nearly half the length of the carapace.

Abdomen relatively the smallest of any species, not more than one-tenth the rest of the body, wider than long; anal sinus narrow, cut scarcely to the center; papillæ basal.

Sucking disks large, placed well back in the carapace, very close together, equaling about one-fourth the width of the carapace; posterior maxillipeds small and weak; basal plate narrow triangular with an abrupt angle near its center; teeth long and sharp with an accessory spur at the base of the outer one.

Antennæ large and well armed. Swimming legs very short, none of them reaching the edge of the carapace; lobes on both joints of the posterior ones flap-like and covered with setæ. Flagella present; no papillæ at the opening of the oviduct.

Length 12 mm.; length of carapace 11.5 mm.; breadth of carapace 13 mm.; length of abdomen 1.2 mm.; breadth 2 mm. Male unknown.

Color grayish white; skin covered with warts and spines on the dorsal surface. Two dark oblique spots on the abdomen.

*Habitat*.—Brazil, South America, on the skin and in the gill cavity of *Salmo* (*Hydrocyon*) *brevidens* Cuvier.

(Named for Johann Natterer, who obtained these Brazilian Arguli together with the specimens of the genus *Dolops*.)

**ARGULUS SALMINI** Krøyer.

Plate XXII, fig. 64.

*Argulus salmini* KRÖYER, Bidrag til Kundskab om Snyltekrebsene. Naturhist. Tidskr., 3die Række, 2 Bind, 1863.—THORELL, Om tvenna Europeiske Argulider, etc. Öfvers. af Kongl. Vetensk.-Akad. Forhandlingar, 21st series, Stockholm, 1864.

Carapace orbicular, wider than long; posterior sinus wide, one-fourth the length of the carapace, cephalic area prominent.

Abdomen very small, about one-sixth the rest of the body, wider than long; anal sinus narrow, not cut to the center, lobes broadly rounded; papillæ basal.

Sucking disks very large, placed well forward and so close together that they almost touch, about one-third the width of the carapace; posterior maxillipeds correspondingly small; basal plate rectangular and armed with short blunt teeth.

Antennæ of medium size and well armed. Swimming legs not reaching the edge of the carapace; lobes on the posterior ones small, boot shaped. Flagella present but no papillæ at the oviduct opening. Male longer and much narrower than the female, particularly in the abdomen; the carapace also in the male overlaps the abdomen, while in the female it barely covers the third legs.

Color a light liver-brown with a narrow dark margin anteriorly on the upper surface of the carapace and a small dark spot at the base of the anal sinus. The grooves which separate the cephalic from the lateral areas are darker and more yellow in color than the rest of the integument. The male lacks the dark anterior margin of the carapace and the dark spot at the base of the anal sinus.

Length 13 mm.; length of carapace 10.4 mm.; breadth of carapace 10.6 mm.; length of abdomen 2.5 mm.; breadth 2.6 mm.

*Habitat*.—Brazil, South America, in the gill cavity of *Salmo*. (*salmini*, from generic name of host.)

#### ARGULUS CHROMIDIS Kröyer.

Plate XXII, fig. 62.

*Argulus chromidis* KRÖYER, Bidrag til Kundskab om Snyltekrebsene, Naturhist. Tidsskr. 3die Række, 2 Bind, 1863.—THORELL, Om tvenna Europeiske Argulider, etc., (Eftvers. af Kongl. Vetensk.-Akad. Forhandlingar, 21st series, Stockholm, 1864.

Carapace obovate, longer than wide, scarcely reaching the third legs; posterior sinus so wide as to carry the lobes away from the thorax and leave a clear space between, and reaching but a quarter the length of the carapace.

Abdomen one-fourth the length of the rest of the body, about as wide as long; anal sinus wide, well rounded, reaching a quarter the length of the abdomen; papillæ basal.

Sucking disks small, about one-seventh the width of the carapace; posterior maxillipeds small, basal plate rectangular, with short, blunt teeth, the central one sharper than the others. Flagella present.

The eggs occupy not merely the trunk, but nearly the whole shield (Kröyer).

Length 6 mm.; length of carapace 4.1 mm.; breadth of carapace 4 mm.; length of abdomen 1.2 mm.; breadth 1.1 mm. Male unknown.

Color a clear yellowish-white, relieved by the dark coffee-brown egg masses.

*Habitat*.—Nicaragua, Central America, in the gill cavity of a species of *Chromis* taken from Lake Nicaragua.

(*chromidis* from generic name of host.)

## ARGULUS ELONGATUS Heller.

Plate XXII, fig. 61.

*Argulus elongatus* HELLER, Beiträge zur Kenntniss der Siphonostomen. Sitzungsab. d. kais. Akad. d. Wissensch., Math.-naturwissensch. Cl., XXV, 1857.—TRORELL, Om tvenna Europeiska Argulider, etc., Öfvers. af Kongl. Vetensk.-Akad. Forhandlingar, 21st series, Stockholm, 1864.

Carapace very short, triangular, wholly without lobes; no posterior sinus. Abdomen one-quarter the length of the rest of the body, longer than wide; anal sinus broad triangular, cut almost to the very base, lobes divergent, acuminate-lanceolate; papillæ basal. Sucking disks medium size, placed well forward; posterior maxillipeds good size; basal plate without teeth but well armed otherwise. Antennæ of normal size and armament. As there are no carapace lobes the swimming legs are left wholly uncovered. No data as to flagella or oviduct papillæ, but inasmuch as Heller has been careful to put in the flagella in the other species he has illustrated, the absence of them in his figure of *elongatus* indicates that he could not find any. Color a yellowish white, very darkly pigmented and speckled; bases of the swimming legs also with circular black spots.

Length 10 mm.; length of carapace 4.3 mm.; breadth of carapace 6 mm.; length of abdomen 2 mm.; breadth 1.9 mm. Male unknown.

The abrupt truncation of the carapace distinguishes this species at once from all others.

*Habitat*.—Brazil. Host unknown.

(*Elongatus* = alludes to the elongated appearance of the body, due to the absence of lobes on the carapace—i. e., the elongation is apparent not real.)

## ARGULUS FOLIACEUS Linnæus.

Plate XXIV, fig. 69.

*Pou des Poissons* BALDNER'S manuscript, 1666.

*Monoculus cauda foliacea plana* LOEFLING, 1750.

*Pou de Gasteroste*, *Pou de la carpe* BAKER, 1753.

*Monoculus foliaceus* LINNÆUS, 1758 and 1761.

*Monoculus piscinus* LINNÆUS, 1761.

*Binoculus gasterosteus* GEOFFROY-SAINT HILAIRE, 1762.

*Insectum aquatum* LEDERMÜLLER, 1764.

*Argulus charon* MÜLLER, 1785.

*Argulus delphinus* MÜLLER, 1785.

*Monoculus argulus* FABRICIUS, 1792-1794.

*Monoculus gyrini* CUVIER, 1798.

*Ozolus gasterostei* LATREILLE, 1802.

*Argulus foliaceus* JURINE, 1806. [This name retained by the various authors given in the historical part, which see.]

Carapace elliptical, longer than wide; posterior sinus narrow, extending two-fifths the length of the carapace.

Abdomen one-fourth the length of the rest of the body, about as



wide as long; anal sinus broad, well rounded, cut nearly to the center; papillæ basal. Sucking disks small, one-sixth the width of the carapace, placed well forward and far apart; posterior maxillipeds large, well armed; basal plate narrowed anteriorly, triangular posteriorly, with three sharp teeth.

Antennæ normal. Swimming legs reaching far beyond the edge of the carapace; lobes on the posterior pair very small, evenly rounded. Flagella present, but no oviduct papillæ in the female. Abdomen in the male considerably elongated, but no copulatory organs except the regular peg and semen vesicle. Color a light green, becoming yellowish where the carapace is thickened.

Length 6-7 mm.; length of carapace 4.2-5 mm.; breadth of carapace 3.5 mm.; length of abdomen 2-2.5 mm.; breadth 1.35 mm.

Male about two-thirds this size; abdomen considerably elongated; anal sinus triangular and cut more deeply.

*Habitat.*—In fresh water almost all over Europe, both on the external skin and in the branchial cavity of fish, including several species of *Gasterosteus*, *Cyprinus carpio* Linnæus, *Abramis brama* Cuvier, *Leuciscus rutilus* Linnæus, *Tinca vulgaris* Cuvier, *Esox lucius* Linnæus, *Perca fluviatilis* Rondelet, *Salmo trutta* Linnæus, and on the tadpoles of *Rana*.

#### ARGULUS PURPUREUS Risso.

Plate XXIII, fig. 65.

*Binoculus bicornutus* RISSO, 1816.

*Agenor purpureus* RISSO, 1826.

*Argulus purpureus* THORELL, 1864.

Carapace elliptical, much longer than broad, with the sides approximately parallel; posterior sinus narrow, extending fully half the length of the carapace; antero-lateral sinuses deep.

Abdomen orbicular, a little longer than wide, entirely covered by the carapace; anal sinus narrow and slit like, extending to the center of the abdomen; papillæ basal; lobes acuminate orbicular. Sucking disks small, one-fifth the width of the carapace, close together; posterior maxillipeds large, well armed; basal plate rectangular, without any central rough area; teeth sharp.

Antennæ strong, well armed. Swimming legs short, slender, scarcely reaching beyond the carapace, lacking flagella; lobes on the posterior pair narrow and long. No oviduct papillæ. Eyes small and semilunar.

This is the only species except *versicolor* which is at all highly colored. Carapace pale blue-green, sparsely spotted with white; three violet bands in either lobe, which widen and fuse anteriorly, while the two inner bands are connected by a narrow line of the same color. Pigment spots on the ovary violet and so arranged as to leave a median line of pure white.

Appendages and ventral surface yellowish brown, deeper at the center; endopodites and exopodites glass-green.

Length 18 mm.; length of carapace 18 mm.; breadth of carapace 10 mm.; length of abdomen 6 mm.; breadth 6 mm. Male about one-third smaller, with only the regular peg and semen vesicle for copulatory organs.

*Habitat*.—Mediterranean at Nice on *Caranx lina* Geoffroy, by Risso, and on *Pagellus erythrinus* Linnaeus, by Thorell. The specimens found by Risso were usually attached to the base of the pectoral fin, and the single specimen found by Thorell was similarly placed.

All Risso's specimens were males, while Thorell's was fortunately a female. The latter seems to think that this species might be regarded as the type of a new genus for which he would propose the name *Agenor* Risso. But the only reasons for this which he can bring forward are the unusual development of the carapace, the absence of flagella, the presence of two lamellæ on the last thoracic segment, and certain slight modifications in the mouth parts. It is very evident that none of these have any generic value.

The shape and markings of *A. giganteus*, as given in the figure by Lucas (1845) are almost exactly the same as those of the present species as figured by Thorell. The color also (yellow finely dotted and traversed lengthwise on either side with a red-brown line) is what might fairly be expected in a *dried* specimen, the only one ever obtained. And then this single specimen was found near Algeria, in the Mediterranean, which is not so very far from Nice. For these reasons and because the specimen was dried, and neither adequately described nor figured it seems best to consider it another specimen of *A. purpureus* until some better data can be obtained.

(*purpureus*=purple, from the color).

#### ARGULUS COREGONI Thorell.

Plate XXIV, figs. 70, 71.

*Argulus coregoni* THORELL, 1864.

Carapace orbicular, a little longer than wide in the female, a little wider than long in the male; posterior sinus about one-third the length of the carapace, as wide as long in the female, narrower in the male and converging so that the tips of the lobes overlap. Abdomen long, elliptical, two-fifths the length of the rest of the body, cut fully to the center with lanceolate-acuminate lobes; papillæ basal.

Sucking disks small, one-sixth the width of the carapace and rather widely separated; posterior maxillipeds large, well armed; basal plate rectangular, teeth stout and sharp.

Antennæ medium size and well armed. Swimming legs reaching beyond the carapace in the female, entirely covered in the male; lobes on the posterior pair very small and well rounded.

In the male there are practically no lobes at all, but the copulatory organs are well developed. The second joint of the second pair of legs has on its posterior surface three rounded protuberances, two of which are ventral, one near the base of the joint and one near the tip, while the third one is dorsal and directly over the first at the base of the joint. The flagella of these legs are longer than those of the first pair.

The third legs carry, on the anterior side of the basal joint, a small rounded knob drawn out at the tip into a soft tooth; the second joint carries a similar protuberance, curved at the tip so that it bends over and offsets the tooth of the basal joint like the fingers of a pair of forceps. The regular peg on the fourth legs appears to be double instead of single.

At the base of the abdomen on either side in the female is a small ovate scale attached to the last segment of the thorax; this is lacking in the male, and yet is one of the things which Thorell proposed for generic differences in *A. purpureus*.

Color of alcoholic specimens green, whitish, or tawny. Length 13 mm.; length of carapace 8.6 mm.; width of carapace 8.5 mm.; length of abdomen 3.9 mm.; breadth 2.7 mm.; male about 0.8 this size.

*Habitat*.—In the larger lakes of central and northern Sweden; in Storsjon and other lakes of Jemtland on *Coregonus lavaretus* Linnaeus, and *Thymallus vulgaris* Nilsson. In the salmon-lakes of Dalsland and in the Vettern on *Salmo trutta* Linnaeus. Found on the external skin instead of the branchial cavity.

Dr. Nystrom in his Observations on the River-fauna of Jemtland (1863) gives a fact in reference to this species which is of particular interest in its bearing on the general question of the relation between these parasites and their hosts. He says: "An unusually large species of *Argulus* (referring to *A. coregoni*) fastens itself at certain times in summer, in large numbers, on the Gwyniad (*Coregonus*), and also, though less readily, on the Grayling. Almost every fish has, during this time, one or several of these bloodsuckers on its body, which bite it till the belly is quite drained of blood. The fishes then hurry in crowds to certain parts of the lake, where probably the currents are colder, and fall in large quantities into the nets which are there spread for them. This fishing lasts but a short time, perhaps two days only, but produces during that time in some localities several tons of fish." (See the account of *catostomi* given on p. 651).

(*coregonus*=generic name of its most common host.)

#### ARGULUS MELITA Van Beneden.

Plate XXIII, fig. 66.

*Argulus melita* VAN BENEDEN, 1891.

Carapace elliptical; antero-lateral sinuses situated far back opposite the sucking disks and cut in very deeply, leaving the cephalic area

sharply marked off from the remainder of the carapace, and lunate or semielliptical in shape; posterior sinus broad triangular, less than a quarter the length of the carapace, wider than deep. Abdomen elliptical, two-fifths the length of the rest of the body; anal sinus broadly triangular, cut to the center; lobes acute and flaring at the tips; papillæ basal. Sucking disks large, one-quarter the width of the carapace, situated far back, and widely separated; posterior maxillipeds small and poorly armed; basal plate well rounded, with only two teeth. Antennæ large and well armed.

Swimming legs long, reaching far beyond the carapace; lobes on the posterior pair narrow sickle-shaped, much elongated.

Color a fleshy pink, ornamented with lines and bands of dark pigment; the latter include a broad longitudinal band between the eyes, an oval area in the center of each carapace lobe, the two areas connected by three transverse lines, and an oval area in the center of each lobe of the abdomen, connected anteriorly by a single transverse line.

Length 7 mm.; length of carapace 4.4 mm.; breadth of carapace 3 mm.; length of abdomen 2 mm.; breadth 1.3 mm. Male unknown.

*Habitat*.—From Senegal, in the Bay of Dakar, on a species of shark.

(*Melita* = the name of the yacht of M. Chevreux, who found the parasite and sent it to Van Beneden.)

#### ARGULUS DACTYLOPTERI Thorell.

Plate XXIII, figs. 67, 68.

*Argulus dactylopteri* THORELL, 1864.

Carapace elliptical; cephalic area projecting considerably beyond the outline of the remainder of the carapace, leaving ear-like appendages on either side. Those in the female are of medium size and are situated in front of the sinus; those in the male are very large and protrude posterior to the sinus, giving the anterior portion of the carapace a three-lobed appearance. Posterior sinus broadly triangular, about as wide as deep, leaving well-rounded lobes. Abdomen broadly triangular, about one-third the length of the rest of the body; anal sinus narrow, about one-third the length of the abdomen; lobes rounded acuminate; anal papillæ very minute and basal.

Sucking disks small, less than one-sixth the width of the carapace; posterior maxillipeds rather poorly armed; basal plate with minute teeth along its outer border in addition to the three on its posterior border. Antennæ with stout auxiliary spines in addition to the regular ones on the basal joints. Swimming legs without flagella; just reaching the margin in the female, extending beyond in the male.

Color grayish white in alcoholic specimens, the female with two violet bands along the dorsal surface of the thorax made up of small spots of the same color.

Length 7-8 mm.; length of carapace 5 mm.; breadth of carapace

5 mm.; length of abdomen 1.85 mm.; breadth 2.2 mm. Male about five-sevenths this size.

*Habitat*.—The East Indian Ocean in the branchial cavity of *Dactylopterus volitans* Linnaeus.

(*dactylopteri*, from its host.)

#### ARGULUS INDICUS Weber

*Argulus indicus* WEBER, 1892.

Female similar to *foliaceus*, ou. with a carapace wider than long and overlapping the abdomen. Abdomen about 0.25, wider than long, with a short, narrow sinus.

Swimming legs long; lobes of the last pair hatchet-shaped and half as long as the legs themselves; anterior pairs with flagella. No color given and the only figure one of the posterior legs.

*Habitat*, from the East Indian Archipelago. Host unknown. Single specimen a female.

(*Indicus*, of or belonging to India).

#### ARGULUS AFRICANUS Thiele.

*Argulus africanus* THIELE, 1901.

Female similar to *foliaceus* but with a broader shield; abdomen with shorter rounded lappets. Lobes on the posterior legs hatchet-shaped, as in *indicus*, but smaller; anterior antennæ stout. In the male the carapace and abdomen are longer and narrower than in the female. In addition to the regular peg and semen receptacle the second leg carries a stout papillary wart on the posterior side opposite the base of the exopodite of the third leg. The third leg itself is covered with numerous papillary warts, especially on its dorsal and anterior surfaces. The basal plate is small, oval, and pointed anteriorly. No color given; no figure published.

Length in both sexes 7 mm.; width in female 4.5 mm.; in male 4.

*Habitat*.—Numerous specimens from Langenburg on species of *Claria*, a female from Albert Edward Sea and a female from the Nile. (*Africanus*=of or belonging to Africa.)

#### ARGULUS JAPONICUS Thiele.

*Argulus japonicus* THIELE, 1901.

Female similar to *foliaceus*, but carapace more abruptly rounded posteriorly, broader, and somewhat narrowed anteriorly.

Swimming legs tolerably long; lobes of the last pair small and rounded. Abdomen terminating in two small rounded lobes, widely separated. Color brownish; no figure published.

Length of the single specimen 4 mm.; breadth 2.7 mm.

*Habitat*.—From Yeddo, Japan. Host unknown. Single specimen, a female.

(*Japonicus*=of or belonging to Japan.)

## ARGULUS SCUTIFORMIS Thiele

*Argulus scutiformis* THIELE, 1901.

The male has an oval shield which covers half the abdomen; anterolateral sinuses very deep. Anal sinus of abdomen very short, leaving short rounded lobes. Spines on the first antennæ reenforced. Posterior maxillipeds short and stout, with short sharp teeth; basal plate very large and covered with papillary warts. Swimming legs completely covered by the carapace; flagella on the second legs rudimentary.

No copulatory organs except the regular peg and semen receptacle. Color brownish; no figure published.

Length 12 mm.; width 8 mm. Female unknown.

*Habitat*.—The single specimen is in the Vienna Museum and came from Japan. Host unknown.

(*scutum*=shield, *forma*=shape.)

## ARGULUS PHOXINI Leydig.

Plate XXVII, fig. 91.

*Argulus phoxini* LEYDIG, 1871.

Carapace orbicular, about as wide as long; anterolateral sinuses shallow. Grooves between the cephalic area and the lateral lobes well defined, separating the two sharply; lobes curved inward toward each other till they almost meet posteriorly. Ribs supporting the carapace well defined, the longitudinal ones forked at the anterior end as in *foliaceus*; abdomen elliptical, more than three-fifths the length of the rest of the body; anal sinus cut beyond the center; lobes acute and flaring at the tips; papillæ lateral, about one-fourth the distance from the base of the sinus.

Sucking disks small, less than 0.16, widely separated; rays composed of elliptical rods placed end to end. Posterior maxillipeds rather small but well armed; basal plate elliptical, thickly covered with spines.

Swimming legs reaching beyond the edge of the carapace; lobes on the posterior pair small and orbicular with no trace of a boot-shape. In the male the testes are very large, filling the entire basal portion of the abdomen. The peg is covered with long finger-like protuberances or papillæ, while the receptacle takes on a peculiar warty or knobbed appearance, due to numerous small protuberances scattered over its surface.

In addition to these there is on the anterior margin of the basipods of the third legs a pair of accessory organs consisting of a curved hook at the base of the terminal joint and a short papilla thickly covered with spines opposite the hook at the distal end of the second joint. On the posterior margin of the basal joint of the second legs is a knobbed protuberance somewhat similar to the receptacle in appearance.

*Color.*—Yellowish horn-color, with spots of brown pigment thickly scattered over the dorsal and ventral surfaces; spines and hooks brown.

Length, 8 mm.; length of carapace, 4.8 mm.; breadth of carapace, 5 mm.; length of abdomen, 3 mm.; breadth, 2 mm. Female unknown.

*Habitat.*—From Tübingen, on a species of dace or minnow, *Phoxinus phoxinus*.

(*phoxinus*=generic name of host.)

#### Genus CHONOPELTIS Thiele.

This genus differs from both *Argulus* and *Dolops* in the complete suppression of the first antennæ. The simple second antennæ are present, and are similar in all respects to those on the other two genera. This takes away entirely from the antennæ the acquired function of prehension, and leaves them in their original condition as tactile organs.

There is also an entire absence of spines on the ventral surface of the carapace, so that the animal must depend wholly on its maxillipeds for fastening itself to its host.

This genus resembles *Argulus* and is unlike *Dolops* in that the anterior maxillipeds are modified into sucking disks.

On the other hand, it resembles *Dolops* and is unlike *Argulus* in the complete suppression of the preoral sting.

The posterior maxillipeds and the swimming legs are similar to those of *Argulus*.

( $\chi\acute{o}\nu\eta$ =a funnel,  $\pi\acute{\epsilon}\lambda\tau\eta$ =shield.)

#### CHONOPELTIS INERMIS Thiele.

*Chonopeltis inermis* THIELE, 1901.

Cephalic area distinctly separated from the lateral areas by a tangential chitin ridge on either side, between which the antennæ are inserted. Abdomen with acuminate lobes; anal papillæ club-shaped and situated on the sides of the sinus near the base. Basipods of the swimming legs with a fringe of plumose setæ; only the first pair have flagella, and these are rudimentary; lobes on the posterior legs broad and short.

Carapace covering only the first two pairs of legs.

Color blue with numerous dark spots on the back of the thoracic segments. Length of the single specimen 6 mm.; width of the carapace 3.5 mm. Male unknown.

*Habitat.*—From the gill cavity of a species of *Chromis* at Wiedenhafen.

(*inermis*=unarmed.)

## Genus DOLOPS Audouin.

This genus was first described by Audouin in 1837 and afterwards more in detail by Helier in 1857. It differs from both the other genera in the fact that the anterior maxillipeds are not modified into sucking disks, but terminate in strong, sickle-shaped hooks (fig. 73). It resembles *Argulus* and is unlike *Chonopeltis* in the presence of both pairs of antennæ and of spines on the ventral surface. On the other hand it is like *Chonopeltis* in the complete suppression of the preoral sting. The carapace is large, orbicular, or inversely egg-shaped, and in the species so far known it almost covers the legs. In two of the species, *longicauda* and *doradis*, the abdomen is very long and narrow and is cut clear to the base. In *kollari* it is orbicular and resembles closely that of *Argulus megalops* and *A. laticauda*, while in *gayi* it is more like that of *A. alosæ*.

The first antennæ lack the hook on the anterior margin which is present in most of the *Arguli*, and the spines on the basal joints of both pairs are much reduced in number (fig. 74).

The anterior maxillipeds, while not modified into sucking disks, are yet very unlike the posterior ones. They are short and stout; the basal joints are very wide and thick set, but the subsequent ones diminish rapidly in size, so that the terminal joint is only wide enough to receive the base of the large sickle-shaped hook. Opposed to the hook at its base is a short, cylindrical peg, the two fitting together much like the chela of a lobster or crab (fig. 73). The hooks on the two maxillipeds curve in toward each other, and when once driven into the flesh of the host by the powerful muscles within the basal joints they must afford a very secure hold. But it will evidently be quite a task to withdraw them, and one that will consume some time. Hence they are not at all suited for that scuttling motion so characteristic of *Argulus*, and *Dolops* must be a genus which can not move about freely over its host's body.

Again, the wound itself and the subsequent irritation caused by the insertion of these powerful hooks is amply sufficient to cause a strong flow of blood, and obviates the necessity of any sting. Consequently we find the mouth parts consisting of a short conical proboscis between the bases of these anterior maxillipeds, somewhat in front of its position in *Argulus*, and there is no trace of any preoral sting.

The proboscis is formed from the upper and under lips strengthened by a frame work of chitin rods similar to that already described, but there are no maxillæ.

The posterior maxillipeds have the basal plate armed with three teeth, but have no claw on the terminal joint (fig. 72). In its place the tip of the terminal joint is divided into two papillæ of unequal length. The inner, larger one is covered on its ventral surface with two rows of curved spines, four to seven in each row, while the shorter, outer papilla ends in a single row of four or more larger, sickle-



shaped spines. The swimming legs are the same as in *Argulus*, but the third pair have a smaller flagellum in addition to the fully developed ones on the first two pairs. The endopodite of the first pair is without joints. Both basal joints of the posterior pair are furnished with large flat flaps, which underlie the base of the abdomen. The testes of the male are divided longitudinally into narrow lobes, two in some species (*longicauda*, etc.), and three in others (*ranarum*, etc.), in each testis. The accessory copulatory organs in *longicauda* show the regular peg and semen receptacle, with the addition of large finger-like protuberances on the anterior border of the third legs.

In the female of *doralis* the papillæ on the ventral surface connected with the semen receptacles are long and finger-like, and seem to be destitute of spines.

The position of the anal papillæ is not given for any species except *ranarum*; *doralis* has a pair of very rudimentary papillæ at the opening of the oviduct, but in none of the other species are they mentioned.

After this paper had been placed in the printer's hands the U. S. National Museum secured from the Paris Museum specimens of both sexes of the species *Dolops reperta*, *doralis*, *ranarum*, and *bidentata*.

These were kindly placed in the author's hands for examination, and through them the facts relative to those species have been verified.

At the same time the author was fortunate enough to secure Bouvier's Memoir on the genus *Dolops* (1899<sup>2</sup>), from which the facts relative to the other species of the genus have been obtained.

Bouvier deals with external anatomy only, and makes no mention of the internal structure.

So far as could be determined from the preserved specimens just mentioned, the internal anatomy corresponds very closely with that in *Argulus*.

Nothing could be seen of the nervous system except the brain and here and there a peripheral nerve; but these were almost identical in shape and position with the corresponding portions of the nervous system in *Argulus*. There is a heart placed similarly to that in *Argulus*, with a short anterior aorta (Stuhlman), and the blood takes much the same course in circulation, save that in the abdomen the outgoing current passes backward along the margin and returns through the center, just the reverse of the course in *Argulus*.

The digestive system is practically the same as the one already described. Whether the reproductive organs are similar to those in *Argulus* could not be determined with certainty. The semen receptacles of the female are located in the same position in the abdomen, and there are two minute papillæ, one on either side, just posterior to the oviduct opening, where the hollow papillæ were found in *Argulus*, and in all probability these in *Dolops* are similar in function, if not in structure.

The ovary is also similar, being unsymmetrical and occupying the center of the ventral surface.

In the male the testes are much larger than in *Argulus*, but occupy the same position, while we find on the two posterior pairs of legs the accessory peg and semen receptacle as in the former genus.

The chief distinctions between the two genera, therefore, are confined to the anterior maxillipeds and the mouth parts, as given in the artificial key herewith presented.

#### DOLOPS LONGICAUDA Heller.

Plate XXV, fig. 76.

*Gyropeltis longicauda* HELLER, 1857.

*Gyropeltis longicauda* KRÖYER, 1863.

*Gyropeltis longicauda* THORELL, 1864.

*Dolops longicauda* BOUVIER, 1899.

Carapace orbicular, as broad as long; posterior sinus one-fifth the length of the carapace, as broad as long.

Abdomen very long and narrow, one and one-half times the length of the rest of the body; anal sinus broad triangular, cut clear to the base, leaving the lobes very narrow-acuminate and flaring at the tips. Anterior maxillipeds short with few joints, terminated by a stout hook; posterior maxillipeds stout; basal plate with three sharp teeth close together.

Swimming legs rather small; lobes on posterior pair large and wide. Each testis divided longitudinally into two lobes united at their bases; accessory copulatory organs consisting of two finger-like projections from the anterior surface of the basipods of the third pair of legs.

Flagella present. In the male the testes are two-lobed and there are lobes on the posterior border of the basal joints of the third legs in addition to the regular peg and capsule.

Color a dark ashy-gray, with a line of pigment around the edge of the carapace and along the inner border of the abdomen lobes. Length 28 mm.; length of carapace 12 mm.; width of carapace 12 mm.; length of abdomen 16 mm.; breadth of each lobe at the widest place 1.9 mm. Male about the same size.

*Habitat*.—In Brazil on the gills of *Hydrocyon* (*Salmo*) *brevidens*, Cuvier.

(*longa*=long, *cauda*=tail (abdomen).)

#### DOLOPS KOLLARI Heller.

Plate XXV, fig. 77.

*Gyropeltis kollari* HELLER, 1857.

*Gyropeltis kollari* KRÖYER, 1863.

*Gyropeltis kollari* THORELL, 1864.

*Dolops kollari* BOUVIER, 1899.

Carapace large, obcordate, covering all the legs and the base of the abdomen; posterior sinus shallow, one-seventh the length of the cara-

pace, as wide as deep. Abdomen broad elliptical, one-third the length of the rest of the body, as wide as long; anal sinus narrow, extending about one-third the length of the abdomen. Anterior maxillipeds long, stout, many jointed; posterior ones slender; basal plate very wide, teeth blunt and far apart, much resembling those of *A. catostomi* and *A. americanus*.

Antennæ as in *longicauda*. Swimming legs not reaching the edge of the carapace; flagella on the two anterior pairs; lobes on the posterior pair long, narrow, well rounded.

Teeth on the ventral surface of the carapace roughly arranged in transverse rows, those in the area between the antennæ much larger than along the margin. Color a grayish white, without the bands of pigment seen in *longicauda*.

Length, 12 mm.; length of carapace, 10 mm.; breadth of carapace, 9 mm.; length of abdomen, 3 mm.; width, 3 mm. Heller's figure, contains a pair of three-lobed testes in the abdomen, and therefore ought to be a male, contrary to the statement given by Thorell, although the posterior legs do not show any copulatory organs. Bouvier, in his thorough review of the species, does not even mention this fact. But he did examine Heller's type specimen, and distinctly states that only females are known.

*Habitat*.—In Brazil, host unknown. (*kollari* = to Vincenz Kollar, director of the museum from which Heller obtained his specimens.)

#### DOLOPS DORADIS Cornalia.

Plate XXV, fig 75.

*Gyropeltis doradis* CORNALIA, 1860.

*Gyropeltis doradis* THORELL, 1864.

*Dolops doradis* BOUVIER, 1899.

Carapace orbicular, a little wider than long; posterior sinus two-fifths the length of the carapace, wide and well rounded at the base, but the sides approach posteriorly until the lobes almost touch each other. Abdomen long and narrow, one-half the length of the rest of the body; anal sinus narrow, cut clear to the base, leaving very narrow acuminate lobes.

Anterior maxillipeds very wide at the base and so short as to have almost the outline of an equilateral triangle; posterior maxillipeds much longer; basal plate wide, with regular saw teeth close together. Antennæ long and slender; the first pair have no hook upon the anterior margin, but the lateral hooks are much longer than in other species and strongly curved.

Swimming legs reach a trifle beyond the edge of the carapace; the three anterior pairs furnished with flagella; lobes on the two basipod joints of the posterior pair large and broad.

Papillæ connected with the semen receptacles in the abdomen of the

female long and finger-like; papillæ at the opening of the oviduct small and rudimentary.

Color uniform gray or gray-white, spotted with black pigment arranged more or less regularly. Half a millimeter from the edge of the carapace runs a dark line, wide in the center of each side, narrower toward the anterior and posterior ends.

There are also two black triangles in the anterior portion of the carapace, one in front of each lateral eye, consisting of large spots connected at the apices by bands.

The males described by Bouvier are less pigmented than the females. The testes are two-lobed as in *longicanda*. In addition to the regular peg and capsule, there is also a rounded lobe and a long, pointed stylet on the posterior border of the basipod of the second legs, and two unequal papillæ on the anterior border of the basipod of the third legs.

Length, 22.5 mm.; length of carapace, 13 mm.; breadth of carapace, 11 mm.; length of abdomen, 7.5 mm.; width of lobes, 1.5 mm. Male smaller.

*Habitat*.—The two females described by Cornalia were found on the body of a cat-fish (*Doras niger* Valenciennes) which frequents the rivers of Central America.

(*doradis*—from generic name of host.)

In the *Annales de la Societe Entomologique de France*, sér. 1, VI (1837), Bulletin, p. 13, we find the following:

M. Audouin présente deux individus d'un crustacé singulier, qui a beaucoup d'analogie avec l'Argule foliacé de Jurine, mais qui en diffère surtout par l'absence de ventouses aux pattes antérieures, et par sa taille, qui dépasse un centimètre et demi.

Ce crustacé a été trouvé à Cayenne par M. Lacordaire; il est parasite sur un poisson nommé *Aymara*, dont la chair est très-estimée, et qui vit dans toutes les rivières. M. Audouin en donne la description et la regarde comme le type d'un nouveau genre, auquel il assigne le nom de *Dolops*. Il dédie cette espèce à M. Lacordaire.

*Dolops* Lacordairei. Ce nouveau genre sera décrit en détail et figuré.

As Thorell has pointed out, this "*Dolops*?" is identical with Heller's *Gyropeltis*, or at least very closely related to it. The promised description was never published, but M. Geay has recently obtained from practically the same locality (Guiana instead of Brazil), and on exactly the same fish, the "*Aymara*," a species of *Dolops*, which Bouvier (1899<sup>1</sup>) has decided is the same as Audouin's two specimens, and for which he gives the following description:

#### DOLOPS REPERTA Bouvier.

Plate XXVII, fig 87.

*Gyropeltis reperta* BOUVIER, 1899<sup>1</sup>.

*Dolops reperta* BOUVIER, 1899<sup>2</sup>.

Carapace suborbicular, somewhat narrowed anteriorly, nearly covering all the feet. Abdomen broad, triangular, widest at the center,

with well-rounded sides; anal sinus cut deeply, slit-like in shape, leaving blunt lobes.

Anal papillæ small and basal. Anterior maxillipeds with a fleshy lobe or papilla opposite the terminal claw; teeth at the base of the posterior maxillipeds narrow and triangular; those on the basal plate very blunt, but both kinds are enormous, compared with the size of the animal. Antennæ noticeable chiefly for the size of the terminal joint of the second pair, which is about two-thirds as large as the preceding joint.

Swimming legs just reaching the edge of the carapace. The spines covering the ventral surface of the carapace are very large in the frontal region between the antennæ and over the anterior submarginal area, but become smaller posteriorly. They are arranged in two or three irregular rows along the sides of the carapace.

In the males the testes are three-lobed, and there is a conical papilla on the anterior border of the basipod of the third legs. This species is much smaller than Audouin's, being only 7 instead of 15 mm. in length; no other dimensions given.

Color a uniform dark green, with three colorless areas anteriorly, one median and two lateral, the median one narrow oblong, extending forward from the brain to the marginal area of the carapace, the lateral ones triangular, one side parallel to the sides of the median area and the lateral eye in the posterior angle.

*Habitat*.—Guiana, on the fish called "Aymara."

(*reperita*=found again, i. e., Audouin's species rediscovered.)

#### DOLOPS STRIATA Bouvier.

*Gyropeltis striata* BOUVIER, 1899<sup>1</sup>.

*Dolops striata* BOUVIER, 1899<sup>2</sup>.

Carapace elliptical, a little longer than wide. Abdomen narrower than in the preceding species, triangular in shape, with well-rounded sides; anal sinus cut deeper than in *reperita*, leaving the lobes rather more pointed. Anal papillæ small and basal. The protuberance opposite the claw on the anterior maxillipeds is very small; the basal plate of the posterior maxillipeds has three truncated teeth, of which the outer one is much larger than the other two.

The two spines on the ventral surface between the bases of these maxillipeds and a little posterior to them are very large, as wide as they are long, and have a broad, squarely cut tip.

The swimming legs reach considerably beyond the edge of the carapace. The spines on the ventral surface are numerous in the region between the antennæ, and are arranged in distinct transverse lines. Back of the antennæ, in the lateral areas of the carapace, they are grouped in oblique lines, directed outward and backward. These spines wholly disappear opposite the anterior swimming legs, and there are none on the posterior portion of the ventral surface.

Length from 6 to 7 mm.; no other dimensions given. Color, green marbled with blue.

*Habitat*.—Guiana, from a species of *Anguilla*.

(*striata* = striped, in allusion to the lines on the ventral surface caused by the arrangement of the spines.)

DOLOPS BIDENTATA Bouvier.

Plate XXVII, fig. 88.

*Gyropeltis bidentata* BOUVIER, 1899.<sup>1</sup>

*Dolops bidentata* BOUVIER, 1899.<sup>2</sup>

Carapace elliptical, rather large, but not covering the swimming legs. Abdomen broadly elliptical instead of triangular, with a deep anal fissure, which is slit-like in shape; lobes well rounded; anal papillæ small and basal.

Anterior maxillipeds have no protuberance opposite the terminal claw; the second maxillipeds have only two teeth on the posterior margin of the basal plate instead of three; the teeth between the bases of these maxillipeds are long and slender, but rather blunt. Both pairs of antennæ are slender and the anterior ones have no spine on their basal joints.

The spines on the ventral surface of the carapace are slender and about of a size in the region between the antennæ, but those extending backward in a row along the margin of the carapace are much smaller. In the male the testes are two-lobed and the accessory capulatory apparatus is quite complicated. The latter consists of two unequal lobes on the posterior border of the second basipod joint of the second legs, and a pair of very long and convoluted papillæ on the basal joints of the third and fourth legs. Those on the third legs are on the posterior border, those on the fourth legs on the anterior border. This species is very small compared with the preceding ones, being only 2 to 4 mm. in length. Color, a violet brown, due to pigment granules, which are arranged in sinuous lines or in a cobweb pattern.

*Habitat*.—Guiana on a species of *Anguilla*.

(*bidentata* = two-toothed, because it has only two teeth on the basal plate of the second maxillipeds.)

DOLOPS GEAYI Bouvier.

Plate XXV, fig. 78.

*Gyropeltis geayi* BOUVIER, 1897.

*Dolops geayi* BOUVIER, 1899.<sup>2</sup>

Carapace elliptical with a very even curve; not covering the posterior pairs of swimming legs; posterior sinus broad, well-rounded, about one-third the length of the carapace; lobes broad and well-rounded. Abdomen broadly triangular, cut almost to the base; anal sinus tri-

angular and very wide posteriorly, the tips of the acuminate lobes being so far apart that the sides of the abdomen are almost parallel. Anal papillæ of good size and basal. Anterior maxillipeds with an enormous terminal hook, strongly curved; the teeth on the basal plate of the second maxillipeds are small and very blunt.

Swimming legs all project beyond the edge of the carapace, which does not cover even the bases of the posterior pair. The flagella in this species are moderately developed and terminate in a sharp spine; the endopods and exopods are furnished with a double row of plumose setæ; lobes on the basal joints of the posterior legs of good size and boot-shaped.

In the male the testes are two-lobed, with a pair of spherical bodies on either side just anterior to the opening of the vas deferens, which Bouvier could not interpret.

Length of smaller male, 1.95 mm.; length of carapace, 1.29 mm.; width of carapace, 1.2 mm.; length of abdomen, 0.65 mm.; width, 0.55 mm. The larger male had a total length of 3 mm. The female was much smaller. These dimensions must of course be taken as those of rather small specimens.

Color a uniform gray-yellow without any markings.

*Habitat*.—The three specimens were obtained by M. Geay in the month of December between Apure and Arauca, Guiana, and were swimming freely at the surface of the water. (*Geayi* = to M. Geay.)

This finding of them swimming at the surface, in connection with their small size, might suggest that they were the young of some of the other species. This objection is to my mind answered fully by Bouvier when he says, first, that these specimens were sexually mature and therefore must possess all the characteristics of the adult even though they were still small in size. And then in the second place we have seen in the development of the only member of the whole family of Argulidæ whose complete history is known that the young do not become sexually mature till they are about one-quarter the size of the adult. This would mean that even if these were the young of some species the adults could not be anywhere as large as the great majority of the known species of this genus.

#### DOLOPS RANARUM, Stuhlmann.

Plate XXVII, figs. 89, 90.

*Gyropeltis ranarum* STUHLMANN, 1891.

*Dolops ranarum* BOUVIER, 1899.<sup>2</sup>

Carapace somewhat ovate, just reaching the base of the abdomen; posterior sinus rather narrow and about one-third the length of the carapace; lobes well rounded and approaching each other somewhat posteriorly. Abdomen long (about 0.5) and narrow, widest at the center, cut for two-thirds its length. Anal sinus peculiar in shape

owing to the direction of its sides; the base is rather broad and the sides at first flare outward for one-third their length and then turn abruptly inward. The papillæ are situated in the angles formed by these abrupt turns, and are hence marginal, unlike any other known species.

The antennæ are each armed with a pair of large triangular spines upon their basal joints. These also serve as a distinguishing mark, as no other known species possesses them. The teeth on the basal plate of the second maxillipeds are regular saw-teeth and are set close together. The three posterior pairs of swimming legs project considerably beyond the edge of the carapace, but the first pair only just reach it.

Flagella are present only on the first two pairs of legs. There are none on the third pair.

The testes in the male are enormous compared with the size of the animal, and not only occupy all the basal portion (considerably more than half) of the abdomen, but they also bulge out prominently on both the dorsal and ventral surfaces, giving the impression that they are full to bursting. They are each three-lobed (fig. 90).

*Color.*—From a clear brownish yellow to a red-brown, varying with age. The entire dorsal surface is covered with brown pigment spots, small and scattered on the carapace and thorax, larger and closer together on the abdomen. These pigment spots are much branched and each possesses a clear circular area near the center. The pigment on the ventral surface of the abdomen follows the creases between the lobes of the testes, leaving the lobes themselves a free color.

Length, 5 mm. (from 0.5 to 7 mm.); length of carapace, 3.5 mm.; breadth of carapace, 3.5 mm.; length of abdomen, 1.6 mm.; breadth, 1.10 mm.

*Habitat.*—From Buboka in Western Nyansa, Africa, upon frog tadpoles.

(*Ranarum* = of or pertaining to frogs).

These specimens were obtained by Dr. Stuhlmann from the external surface of the tadpoles, where they fix themselves to the skin by the hooks on the anterior maxillipeds.

They were very common, and often 5 or 6 were found upon the same host. Rarely they attached themselves inside the branchial cavity.

That they are similar in their habits to *Argulus* with such differences as are necessitated by the difference in structure of their first maxillipeds, can be seen from the following statement made by Bouvier (1899,<sup>2</sup> p. 13):

Les divers individus étaient fixés à la peau de leur hôte par leur bord antérieur, le reste du corps étant libre; leurs pattes notatoires étaient animées d'un mouvement actif, assurant ainsi les échanges respiratoires. Ils se détachaient librement ou se laissaient enlever avec des pinces, après quoi ils nageaient avec vivacité dans l'eau de la cuvette où ils étaient renfermés.



## DOLOPS DISCOIDALIS Bouvier.

*Gyropeltis kottari* BOUVIER, 1897.

*Gyropeltis discoidalis* BOUVIER, 1899.<sup>1</sup>

*Dolops discoidalis* BOUVIER, 1899.<sup>2</sup>

Carapace orbicular, wider than long; posterior sinus broad and about one-third the length of the carapace; lobes well rounded and separated from the thorax so as to leave a space between. Abdomen short and small, about 0.2, orbicular, somewhat narrowed anteriorly; anal sinus slit-like and not extending more than one-third the length of the abdomen.

The second antennæ have a triangular spine on the basal joint which is fully as large as the joint itself, but there are no spines at the base of the first antennæ.

The teeth on the basal plate of the second maxillipeds are blunt and rather widely separated. The two portions of the chela which terminates each first maxilliped are of about the same size, and each is stiffened with chitin.

The swimming legs just reach the edge of the carapace; each of the basipod joints of the posterior pair carries a very large flap on its posterior margin, those on the first joint being of the typical boot shape.

Each of the three anterior pairs of legs are furnished with flagella, those of the third pair being small, but fully developed.

*Color*.—Grayish green, with large rounded light-colored blotches arranged parallel with the margin of the body. Around the paired and median eyes these blotches fuse into large whitish areas.

Length, 11.8 to 14 mm.; length of carapace, 10 to 12 mm.; breadth of carapace, 10.6 to 14 mm.; length of abdomen, 3 to 3.5 mm.; breadth 4 to 4.3 mm.

*Habitat*.—From the Rio Nuba, in Brazil, on a species of *Platysoma*, called by the natives "Doncella" (*discoidalis*=disk-shaped, alluding to the carapace).

From a careful comparison of the genera and species here described we are enabled to deduce the following as the probable developmental history of the family. The primitive form from which the genera of the family have been developed through a greater or less adaptation to parasitic habits must have been very similar to the free copepods, a form possessing a moderate-sized, flattened carapace, three free thoracic segments, and a more or less lamellar abdomen. The anterior maxillipeds terminated in an ordinary-sized chela; there was no preoral sting; the mouth parts were very little, if at all, protrusible, and the ventral surface was unarmed with spines.

We find no species corresponding with this at the present time, because the first change, and one that must have taken place very quickly after the beginning of parasitic habits, was the making of

some provision whereby the parasite could cling more firmly to its host. This change resulted first in the further development of such appendages as were already adapted for clinging, such as the maxillipeds, etc., and the claws and spines upon these appendages were increased in size and strength or modified in form so as to be still better suited for such a purpose.

Then other appendages, such as the antennæ, etc., which were not originally or normally adapted to clinging or grasping, became gradually so greatly modified as to serve very poorly their original purpose, but are almost entirely given up to the acquired function. Such a condition as this we do find admirably illustrated in several of the so-called "unarmed" species of *Dolops*, such as *ranarum*, *longicauda*, etc.

As a further means toward this same end, prehension, the ventral surface of the carapace is next covered with spines pointing backward, a condition well illustrated by the so-called "armed" species of *Dolops*, such as *reperta*, *striata*, etc.

The wound and the subsequent irritation caused by forcing the enlarged claw-like hooks on the antennæ and the first maxillipeds into the flesh of the host must produce a copious flow of blood for the parasite. But these creatures are naturally very active, and they swim about freely, so that the forcing of their claws into their host, together with the subsequent withdrawal of them every time they wished to change their location, would impede considerably their freedom of motion. Consequently we next find the anterior maxillipeds entirely altered in structure, though still retaining their same function.

The terminal joints, with their stout hooks, are gradually absorbed, and in their place appear the circular sucking disks. These, through the creation of a partial vacuum by means of muscular action, cling as firmly to the skin of the host as did the claws, and they possess the further advantage that their hold can be taken or loosened instantaneously, thereby enabling the copepod to move about quickly over its host's body or to leave it and swim away.

This condition we find realized in the new genus *Chonopeltis*, recently described by Thiele (1901), where the anterior maxillipeds are modified into sucking disks, but otherwise the appendages are the same as in the "unarmed" species of *Dolops*. Curiously enough, there is also in this genus a complete suppression of the spines on the ventral surface, and there are no anterior or prehensile antennæ. Just what significance this may have in regard to the sequence of modifications can only be determined after the early development of the genus has been worked out.

But, while this change from claws to sucking disks in the anterior maxillipeds increases the facility of movement, it also deprives the parasite of his chief means of getting food. The sucking disks are

soft and they do not penetrate or even irritate the skin of the host. Consequently there can be no flow of blood following their use, and some other means for obtaining it must be provided.

This takes the form of a long, pointed sting or piercing organ, which is evertible and situated just in front of the mouth. This being thrust through the skin into the flesh of the host quickly brings a copious flow of blood, which the copepod then sucks up with its proboscis-like mouth parts.

This stage of modification is exemplified in the genus *Argulus*, and is the limit at the present time.

The genus *Argulus*, therefore, which includes three-fourths of all the species in the family, so far from being typical, is really the one which has undergone the greatest modification from the original primitive type. The genus *Dolops*, especially those species which are called "unarmed" by Bouvier, has undergone the least modification and retains most fully its primitive characteristics.

The genus *Chonopeltis* is intermediate between the other two and assists us in interpreting intelligently the various steps in modification which have been brought about by parasitic habits.

#### EXPLANATION OF THE PLATES.

All the drawings for both the text-figures and the plates were made with a camera lucida, unless otherwise stated.

Plate VIII. Newly hatched female larva of *argulus megalops*. *a m*, anterior maxilliped; *br*, brain; *cu*, endopod of first swimming foot; *gl*, skin glands; *p m*, posterior maxilliped; *s b*, side branch of the stomach; *s g*, shell gland; *s r*, semen receptacle; *t h*, tactile hairs.

- IX. Figs. 1-4, *Argulus latus*, ventral and dorsal surfaces, posterior maxilliped and antennæ, all of female.
- X. *Argulus laticauda*, fig. 5, ventral surface of male; fig. 6, dorsal surface of male; fig. 7, posterior legs and abdomen of female; figs. 8 and 9, antennæ and posterior maxilliped of male.
- XI. *Argulus megalops*, fig. 10, ventral surface of female; fig. 11, posterior maxilliped of male; fig. 12, antennæ of female; fig. 13, posterior legs of male showing accessory sexual organs. (See fig. 12 (in the text) for dorsal surface of female.)
- XII. *Argulus alosæ*, figs. 14, 15, 16, and 18, ventral and dorsal surfaces, antennæ, and posterior maxilliped of female; fig. 17, posterior legs and abdomen of male.
- XIII. *Argulus catostomi*, figs. 19-22, ventral and dorsal surfaces, antennæ, and posterior maxilliped of female.
- XIV. *Argulus funduli*, fig. 23, ventral surface of female; figs. 24 and 25, dorsal and ventral surfaces of male; figs. 26 and 27, antennæ and posterior maxilliped of male.
- XV. *Argulus pugettensis*, figs. 28-31, ventral and dorsal surfaces, antennæ, and posterior maxilliped of female.
- XVI. *Argulus lepidostei*, figs. 32, 34, and 35, ventral surface, antennæ, and posterior maxilliped of female; figs. 33 and 36, dorsal surface and posterior legs and abdomen of male.

- Plate XVII. *Argulus stizostethii*, figs. 37-40, ventral and dorsal surfaces, antennæ, and posterior maxilliped of female; fig. 41, posterior legs of male.
- XVIII. *Argulus niger*, figs. 42-45, ventral and dorsal surfaces, posterior maxilliped and antennæ of female.
- XIX. *Argulus maculosus*, figs. 46, 48, and 49, ventral surface, antennæ, and posterior maxilliped of female; figs. 47 and 50, dorsal surface and posterior legs and abdomen of male.
- XX. *Argulus versicolor*, figs. 51, 52, 53, and 55, ventral and dorsal surfaces, posterior maxilliped and antennæ of female; fig. 54, posterior legs and abdomen of male.
- XXI. *Argulus americanus*, figs. 56, 58, and 59, ventral surface, antennæ, and posterior maxilliped, of female; figs. 57 and 60, dorsal surface and posterior legs and abdomen of male.
- XXII. Fig. 61, *Argulus elongatus*, female (after Heller); fig. 62, *Argulus chromidis*, female (after Kröyer); fig. 63, *Argulus nattereri*, female (after Kröyer); fig. 64, *Argulus saluini*, female (after Kröyer).
- XXIII. Fig. 65, *Argulus purpureus*, female (after Thorell); fig. 66, *Argulus melita*, female (after Van Beneden); figs. 67 and 68, *Argulus dactylopteri*, male and female (after Thorell).
- XXIV. Fig. 69, *Argulus foliaceus*, male (original drawing); figs. 70 and 71, *Argulus coregoni*, female and male (after Thorell); fig. 72, *Dolops longicauda*, posterior maxilliped of female (after Heller).
- XXV. Fig. 73, *Dolops longicauda*, anterior maxilliped of female (after Heller); fig. 74, *Dolops doradis*, antennæ of female (after Cornalia); fig. 75, *Dolops doradis*, dorsal surface of female (after Cornalia); fig. 76, *Dolops longicauda*, dorsal surface of male (after Heller); fig. 77, *Dolops kollari*, dorsal surface of male (after Heller); fig. 78, *Dolops geayi*, dorsal surface of male (after Bouvier).
- XXVI. Microphotographs of some North American Arguli. Fig. 79, *Argulus laticauda*, male; fig. 80, *Argulus alosæ*, female; fig. 81, *Argulus megalops*, male; fig. 82, *Argulus maculosus*, female; fig. 83, *Argulus versicolor*, female; fig. 84, *Argulus americanus*, male; figs. 85 and 86, ventral and dorsal surfaces of *Argulus americanus*, female; figs. 79, 81, 83, and 84 are of living specimens; figs. 80, 82, 85, and 86 are of preserved specimens.
- XXVII. Fig. 87, *Dolops reperta*, dorsal surface of female (original); fig. 88, *Dolops bidentata*, dorsal surface of male (original); fig. 89, *Dolops ranarum*, dorsal surface of female (original); fig. 90, abdomen of male, same species (original); fig. 91, *Argulus phocini*, dorsal surface of male (after Leydig).